The Main Injector Particle Production Experiment at Fermilab

Rajendran Raja
Fermilab

- Beam
- MIPP experiment
  - » Physics motivation
- Particle ID
- Some results
- Upgrade plans

MIPP collaboration list

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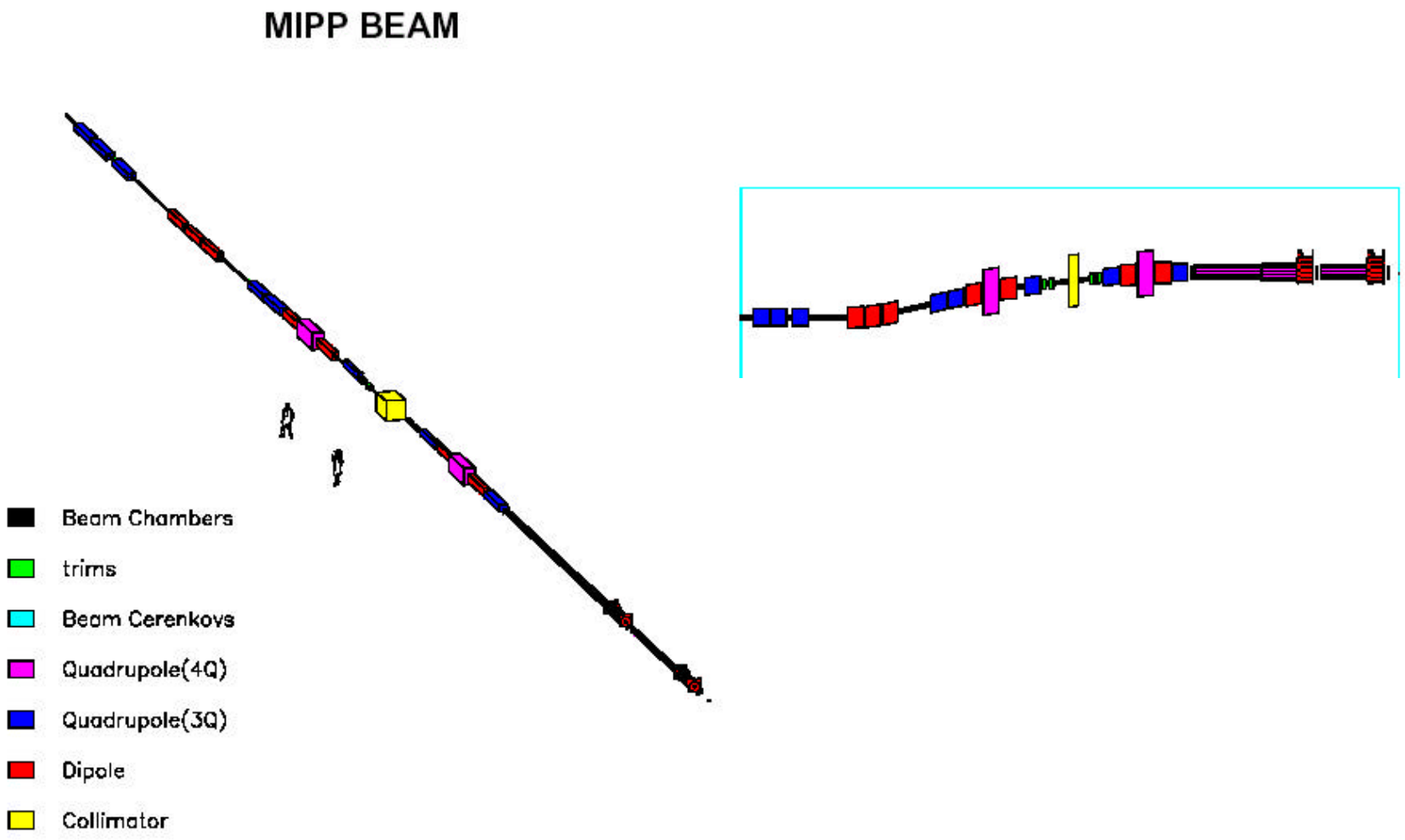
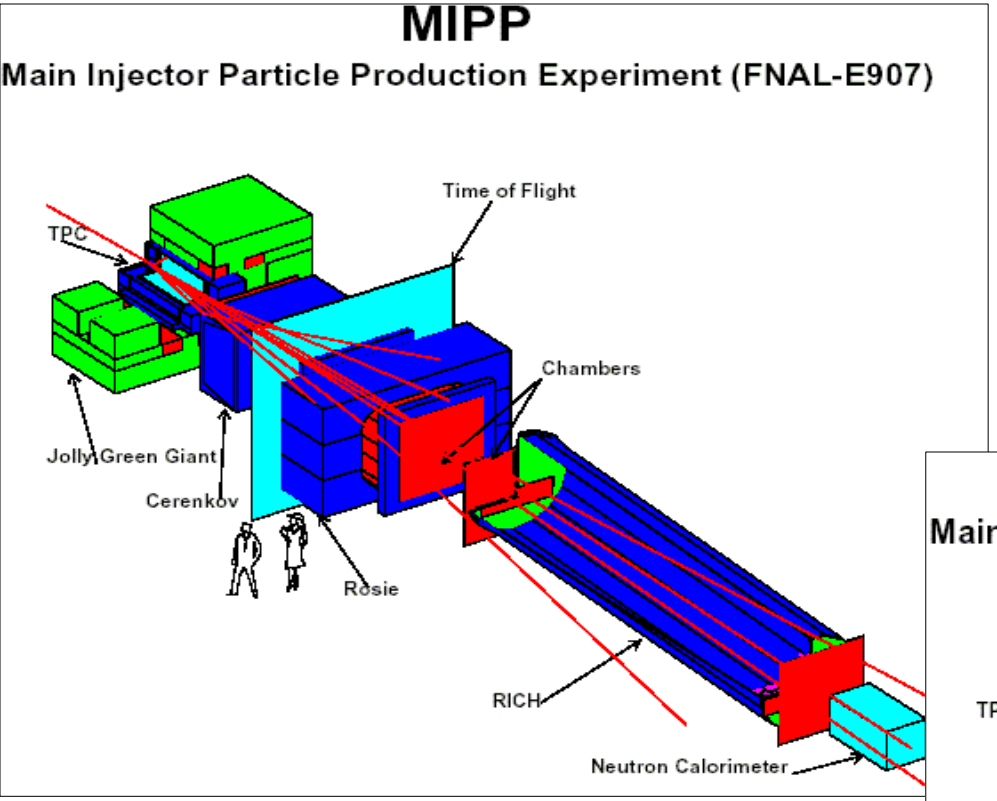
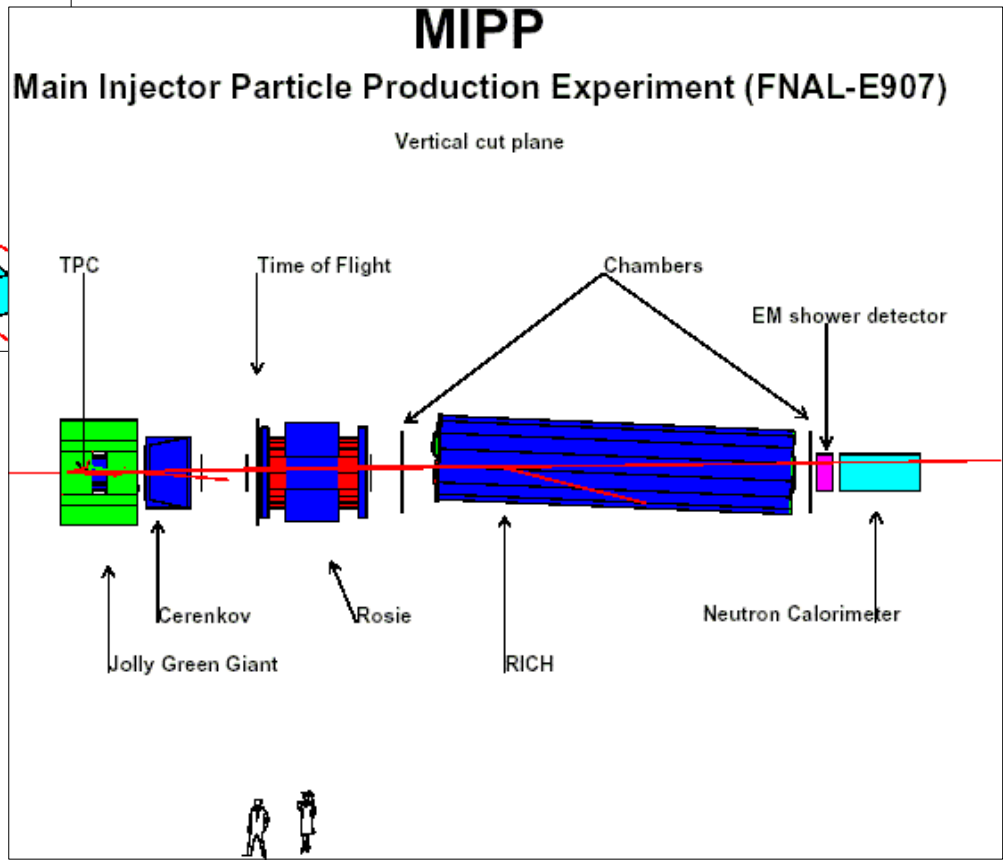
MIPP Secondary Beam

Installed in 2003. Delivering slow spill commissioning beam (40GeV/c positives since February 2004). Finished Engineering run in Aug 2004.




MIPP
Main Injector Particle Production Experiment (FNAL-E907)
Time of Flight
TPC
Chambers
Jolly Green Giant
Cerenkov
Rosie
RICH
Neutron Calorimeter


MIPP
Main Injector Particle Production Experiment (FNAL-E907)
Vertical cut plane
TPC
Time of Flight
Chambers
EM shower detector
Cerenkov
Rosie
Neutron Calorimeter
Jolly Green Giant
RICH

Status of MIPP Now- Collision Hall

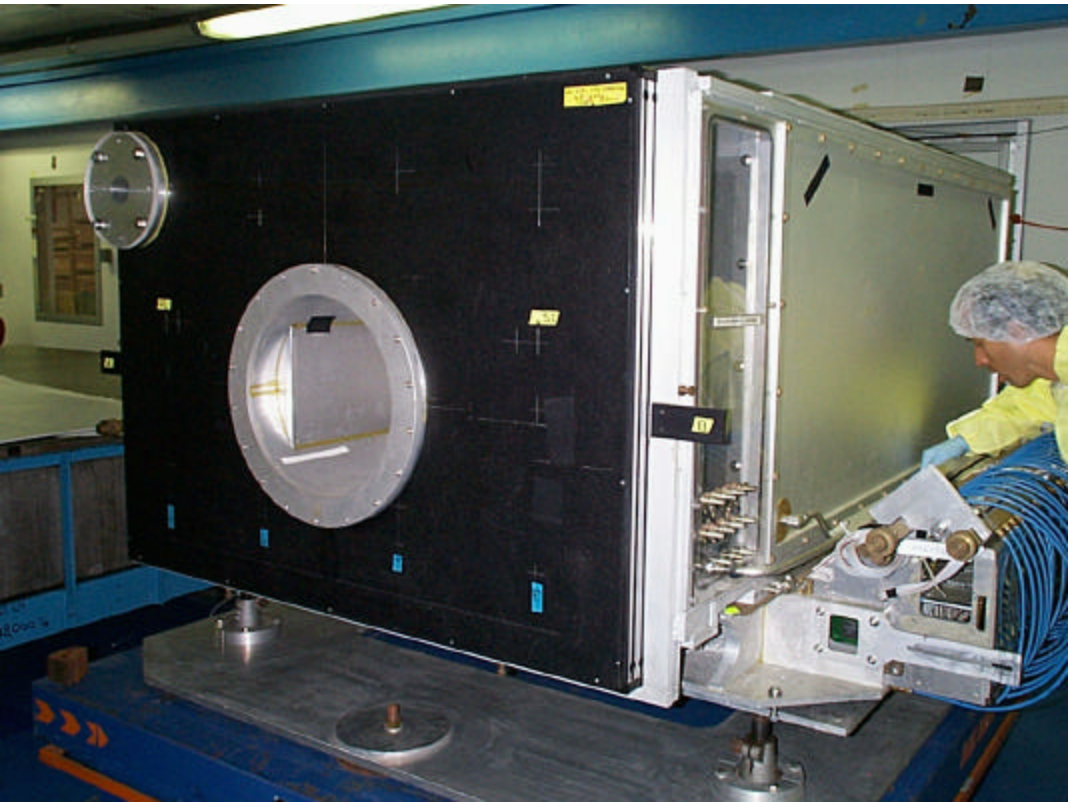
Brief Description of Experiment

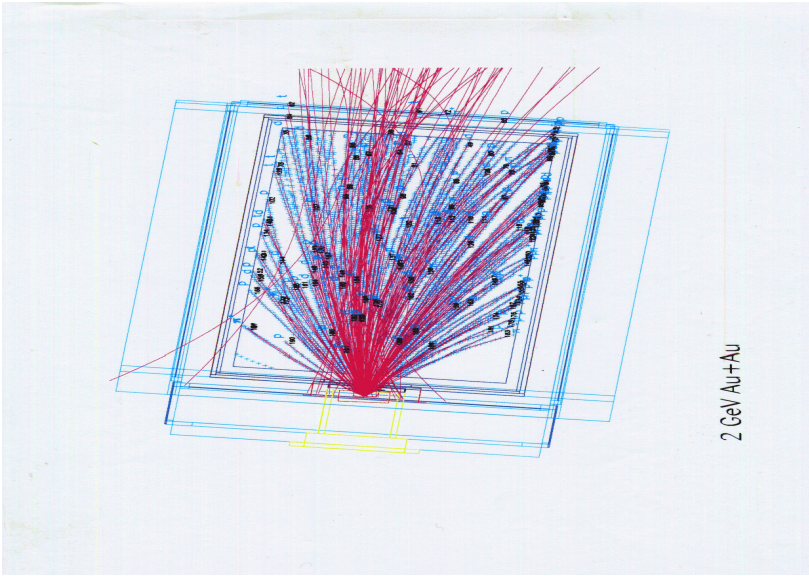
- Approved November 2001
- Situated in Meson Center 7
- Uses 120GeV Main Injector Primary protons to produce secondary beams of $\pi^{\pm}$ $K^{\pm}$ $p^{\pm}$ from 5 GeV/c to 100 GeV/c to measure particle production cross sections of various nuclei including hydrogen.
- Using a TPC we measure momenta of ~all charged particles produced in the interaction and identify the charged particles in the final state using a combination of dE/dx, ToF, differential Cherenkov and RICH technologies.
- Open Geometry- Lower systematics. TPC gives high statistics. Existing data poor quality.

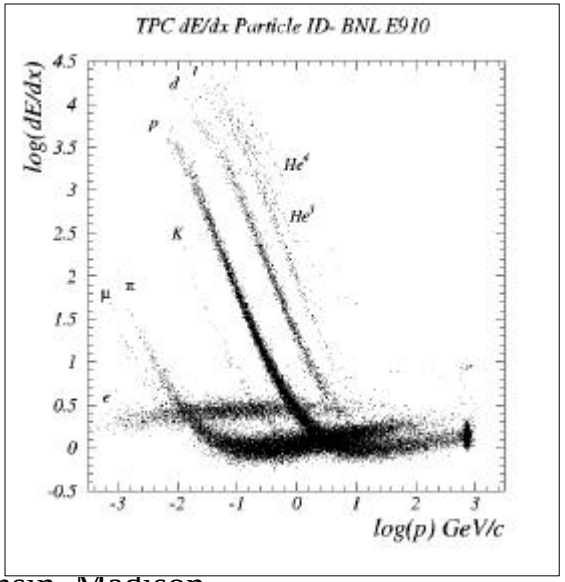
MIPP-TPC

- This Time Projection Chamber, built by the BEVALAC group at LBL for heavy ion studies currently sits in the E-910 particle production experiment at BNL, that has completed data taking. It took approximately $3million to construct.
- Can handle high multiplicity events. Time to drift across TPC=16 μs.
- Electronic equivalent of bubble chamber, high acceptance, with dE/dx capabilities. Dead time 16μs. i.e unreacted beam swept out in 8μs. Can tolerate 10^5 particles per second going through it.
- Can handle data taking rate ~60Hz with current electronics. Can increase this to ~1000 Hz with an upgrade.
- TPC dimensions of 96 x 75 x 150 cm.

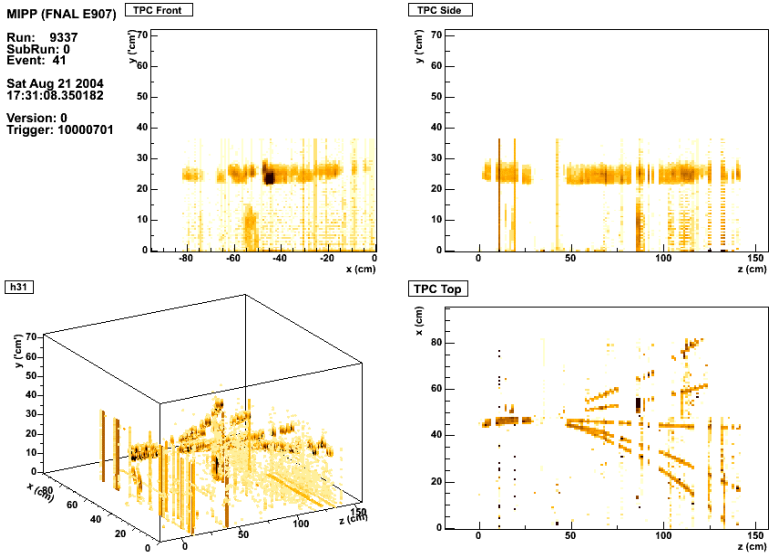
TPC

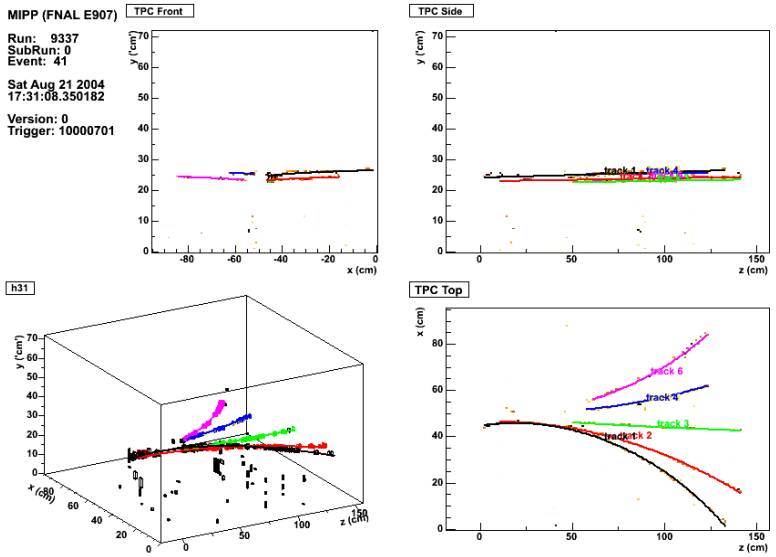


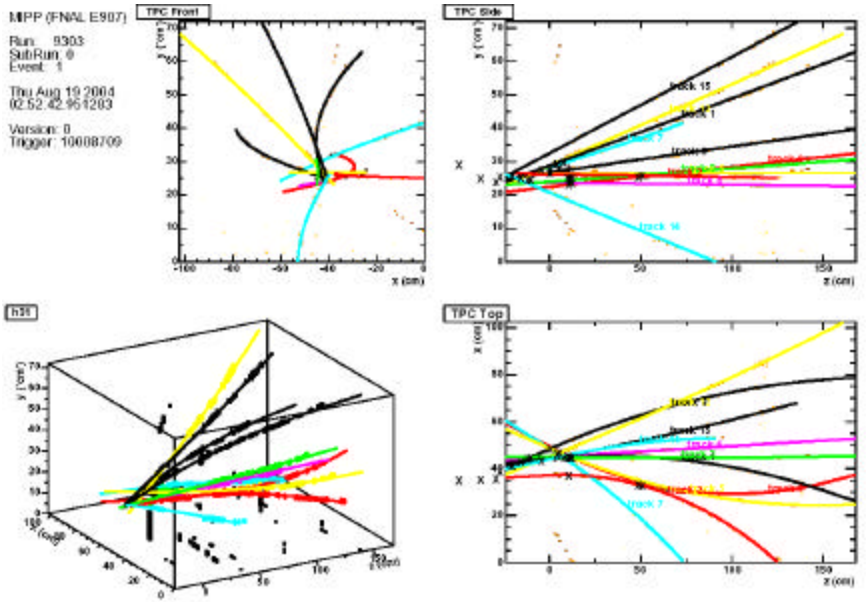

2 GeV Au+Au

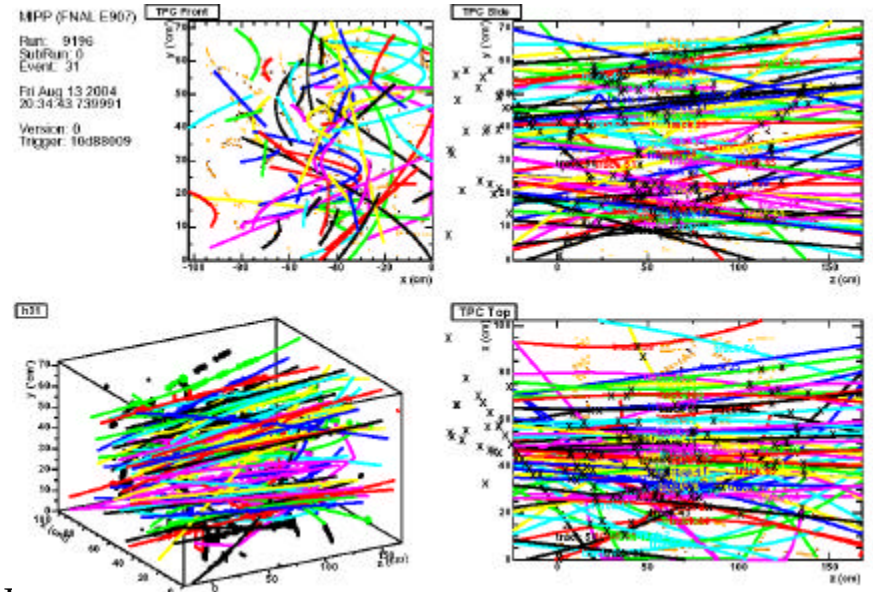

TPC dE/dx Particle ID- BNL E910
log(dE/dx)
log(p) GeV/c
d
p
K
π
μ
e
He4
He3

Preliminary results from Engineering run

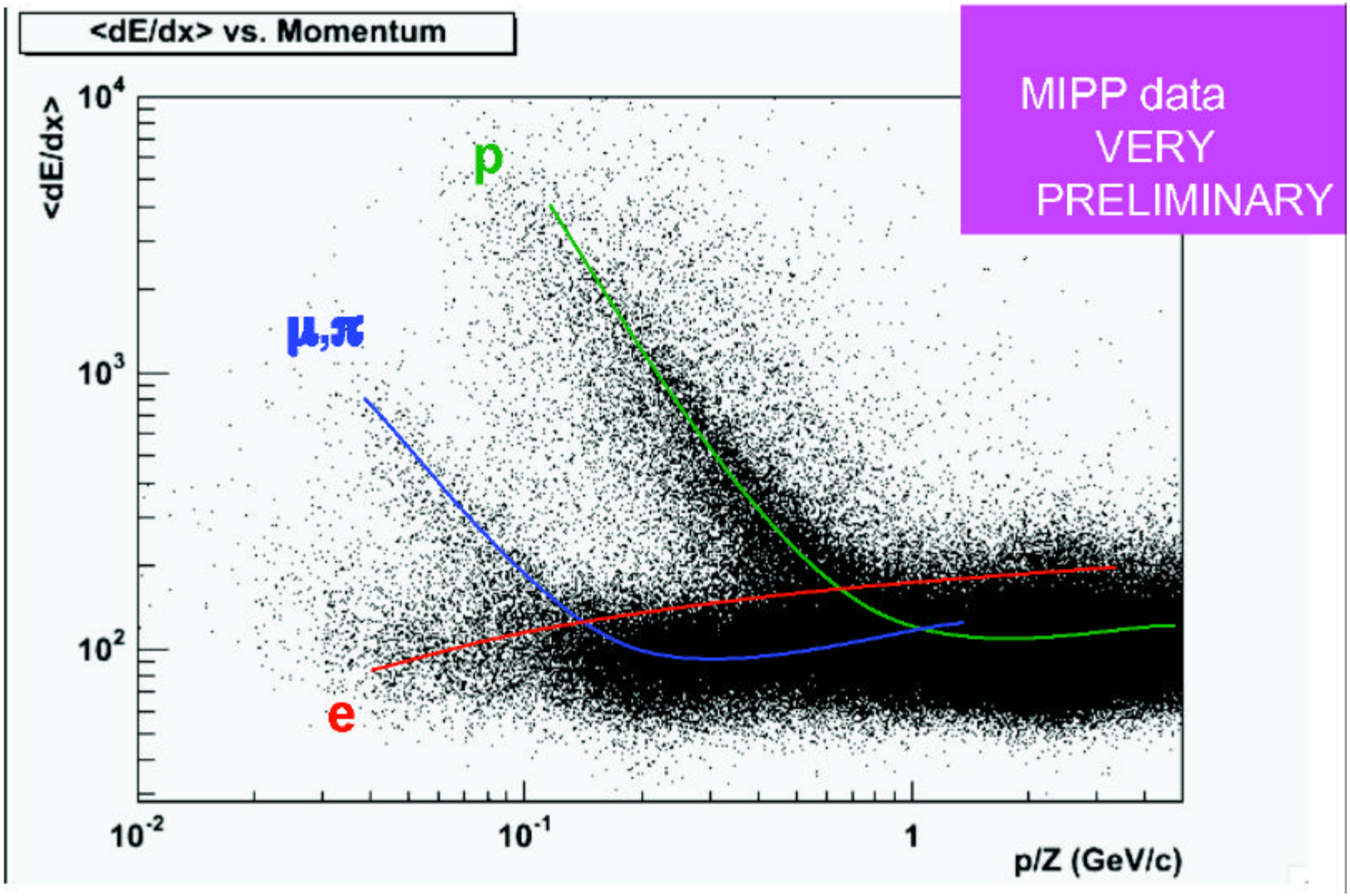




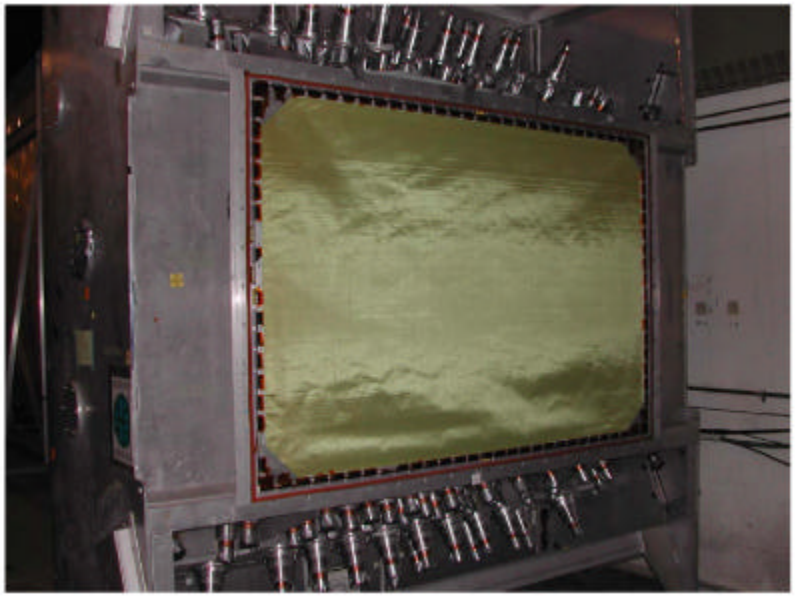




MIPP TPC DATA!



MIPP Cherenkov

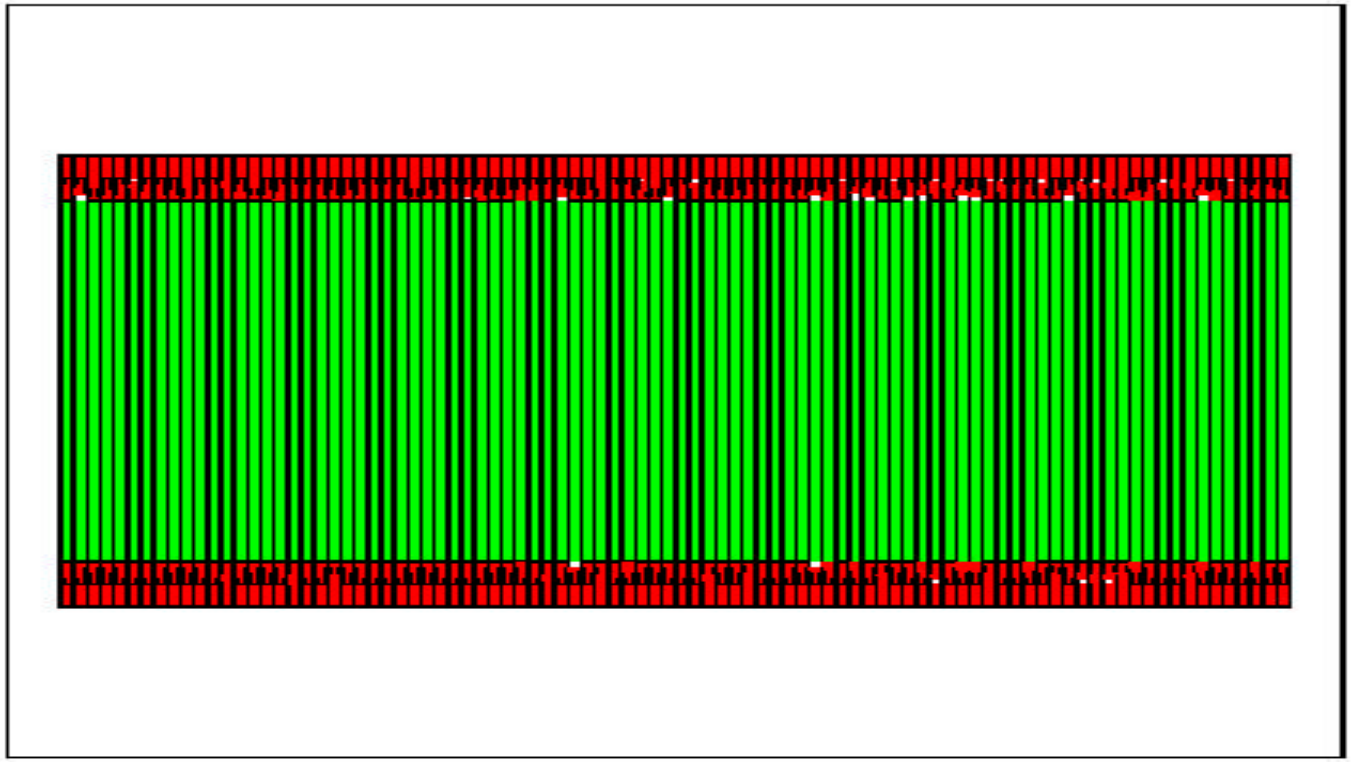


Time of Flight

- Time of flight ($220K) . Designed and built by MIPP

5cmx 5cm square scintillator bars in Rosie aperture, 10cmx10cm outside. ~ 150ps resolution.

MIPP- Time of flight system

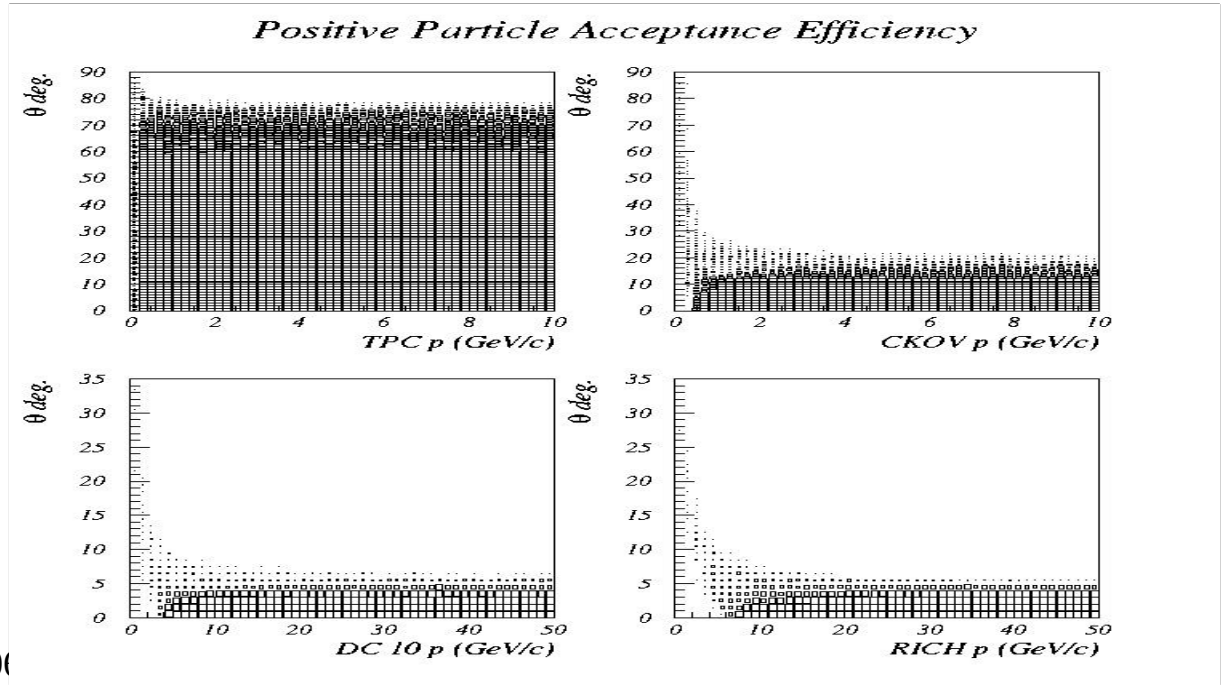


Calorimeters

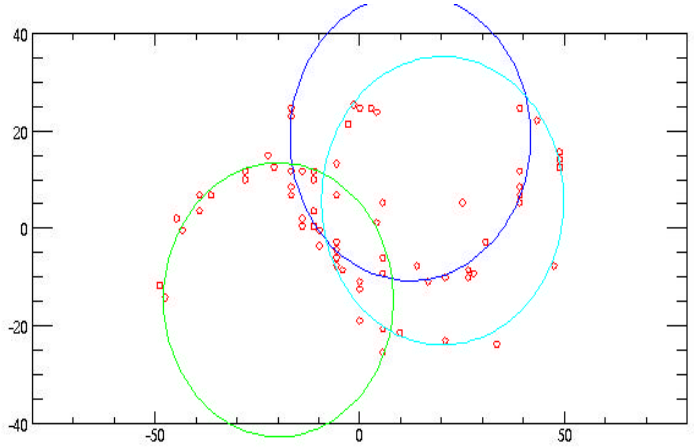
EM calorimeter followed by hadron calorimeter

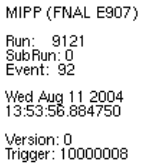
Particle acceptances and resolutions

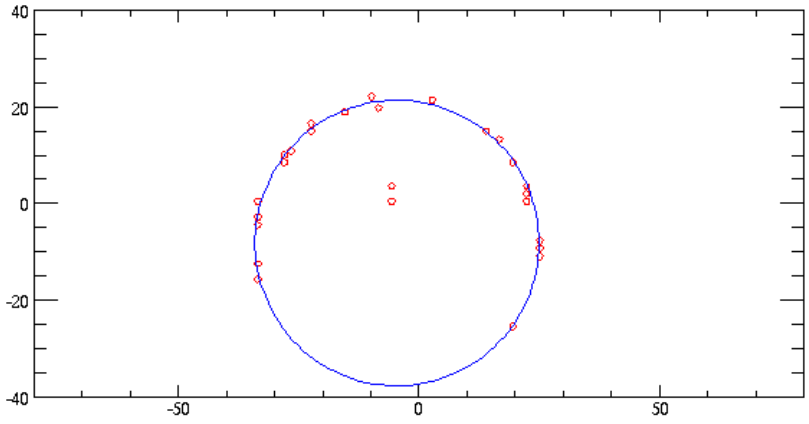
- a)10 Hits in TPC
- b)a hit in the Cerenkov
- c)a hit in Drift Chamber 10 (just before RICH)
- d)Passage through mid-Z plane of RICH.
- Regular Target and NUMI target
- Four cases of particles considered
- (Cumulative AND)

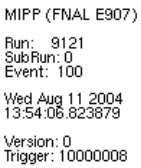


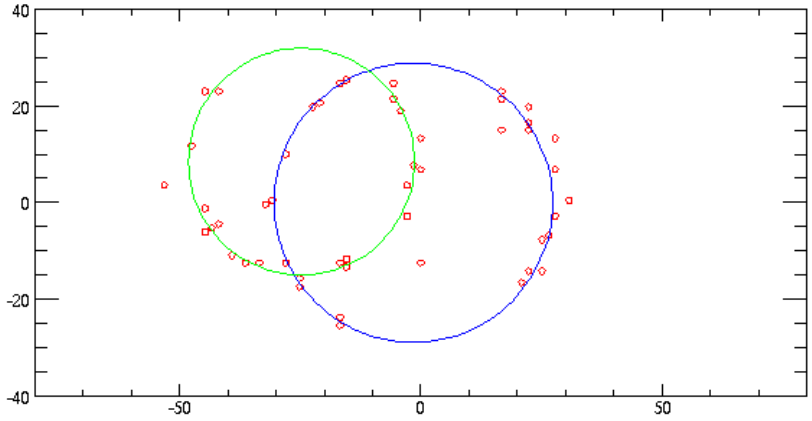
RICH rings pattern recognized



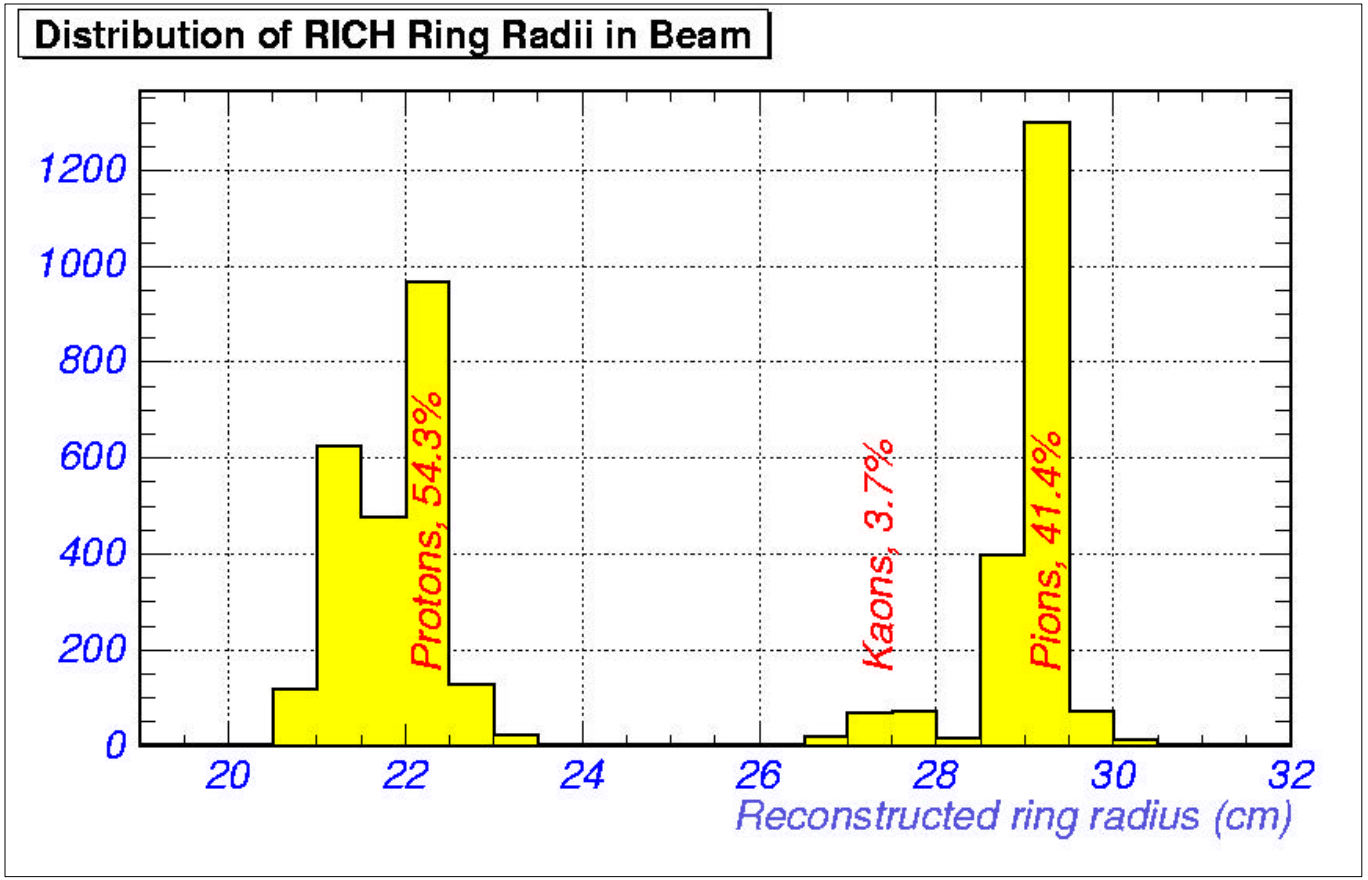






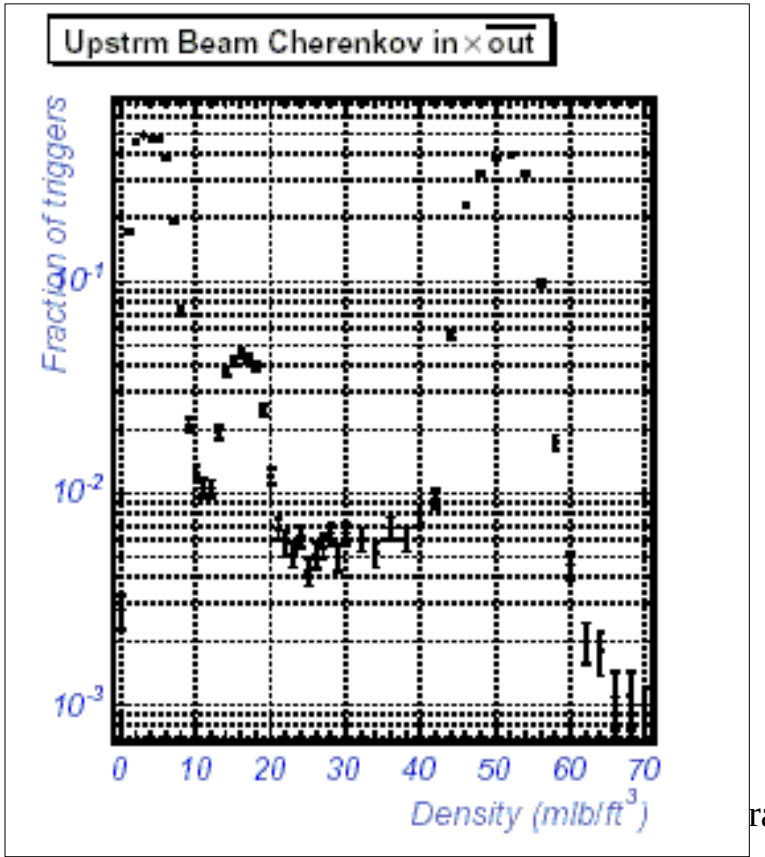


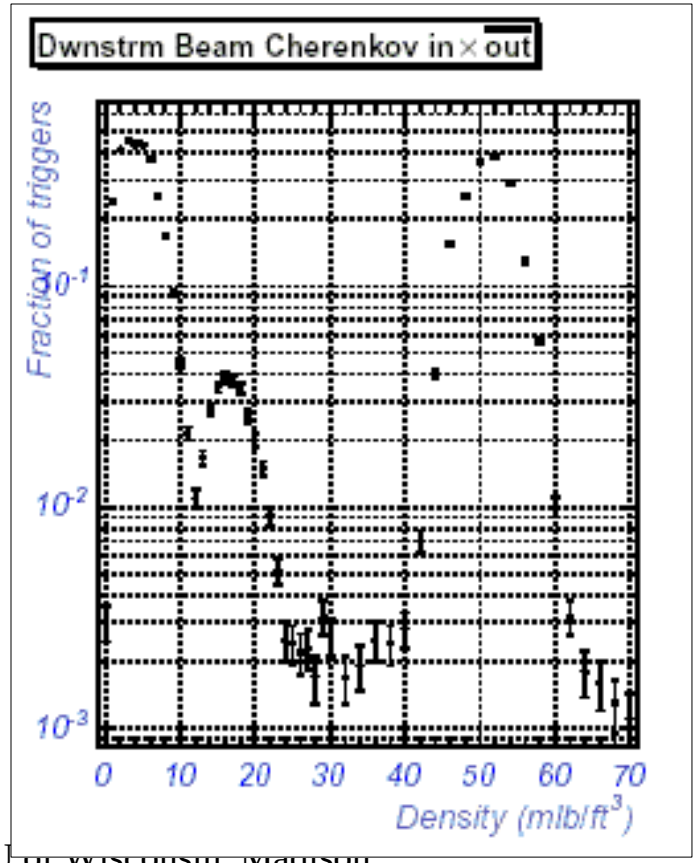
RICH radii for + 40 GeV beam triggers



Beam Cherenkovs

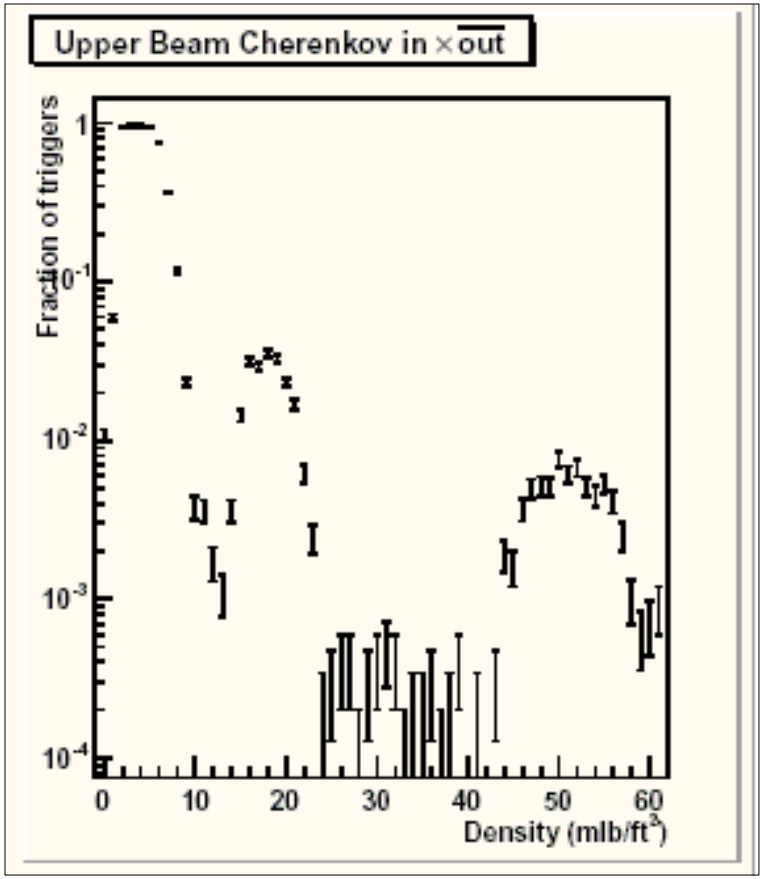
- Pressure curve Automated- Mini-Daq-APACS 30 minutes per pressure curve.+40GeV/c beam.

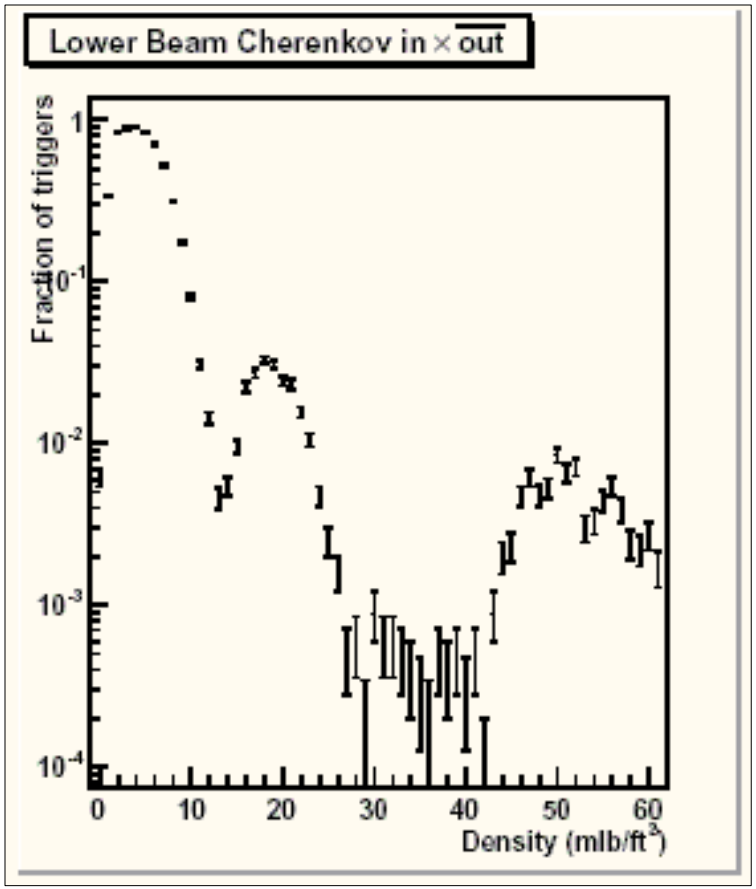




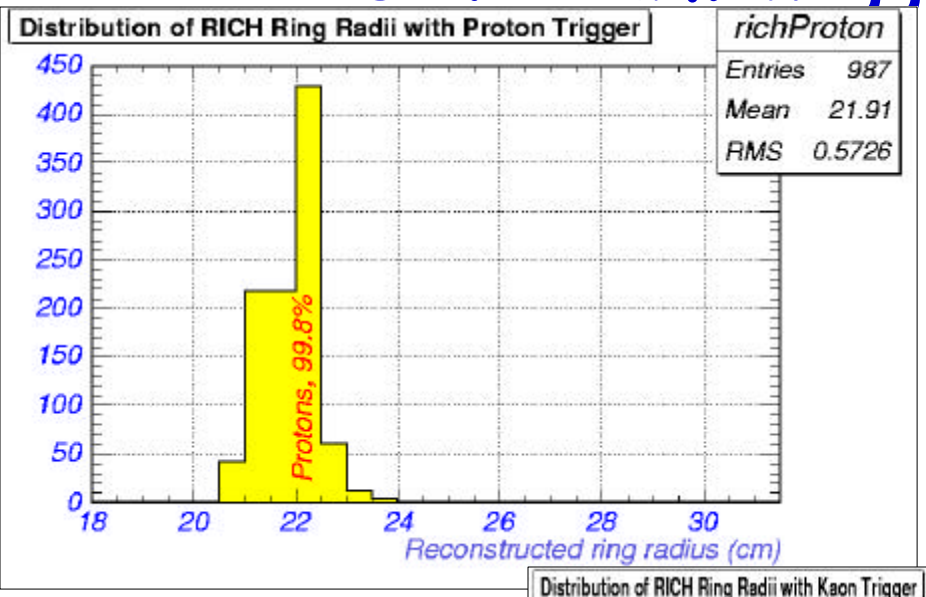
Beam Cherenkovs

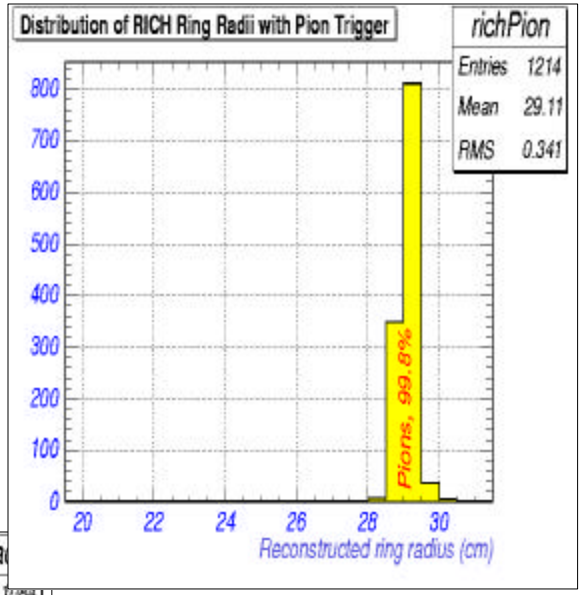
- 40 GeV/c negative beam

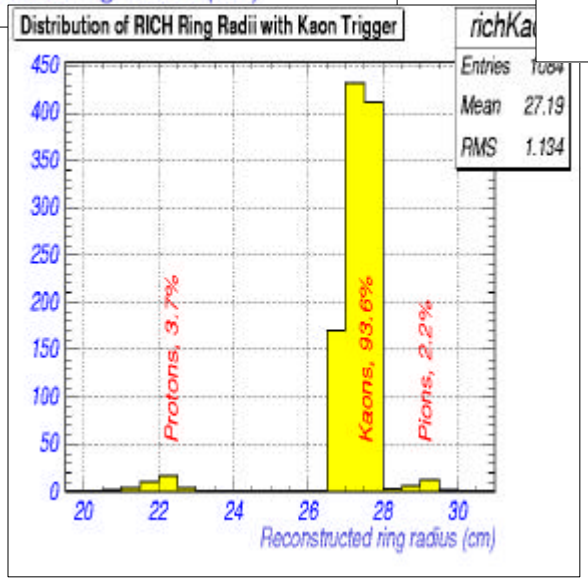




Comparing Beam Cherenkov to RICH for +40 GeV beam triggers-No additional cuts!

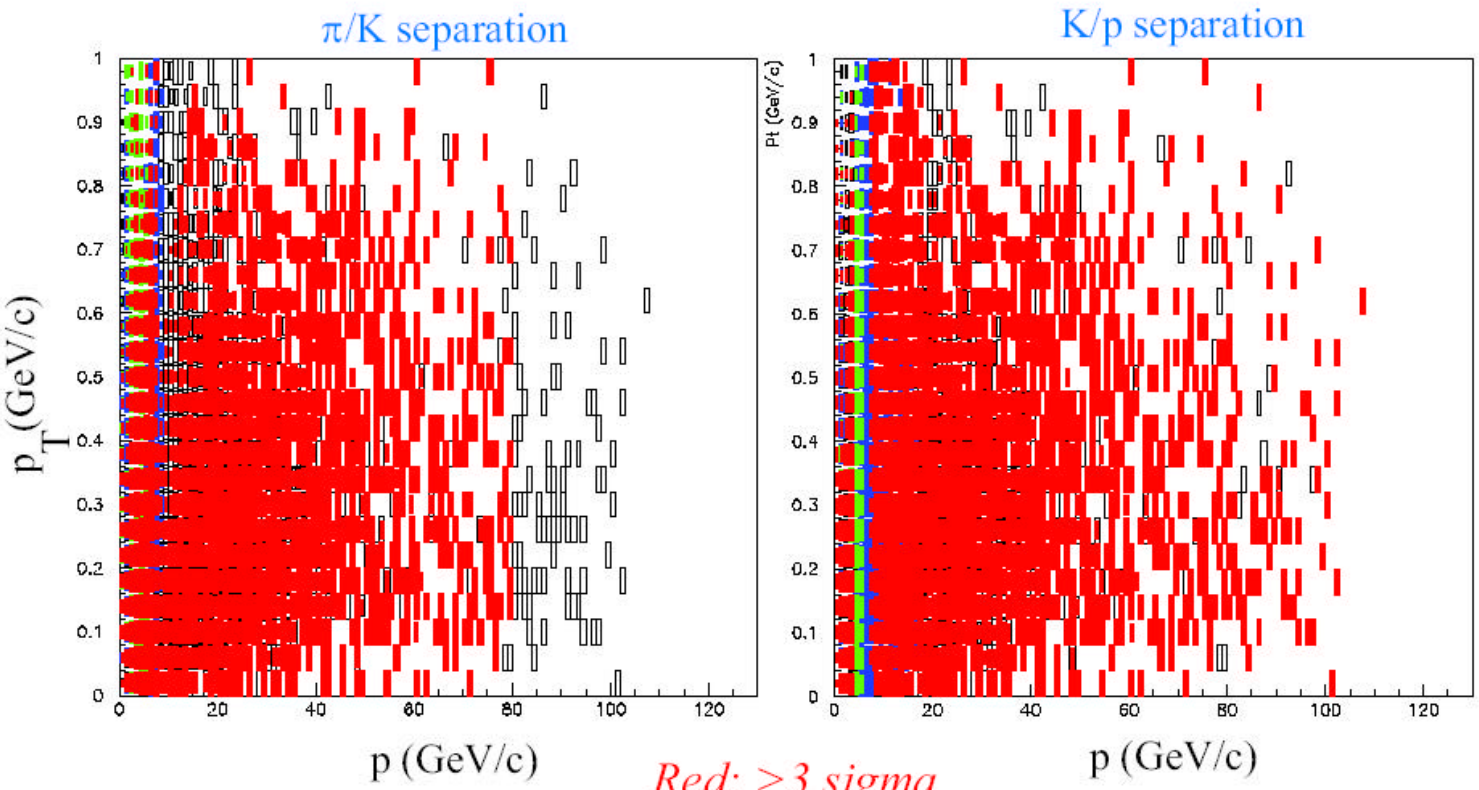






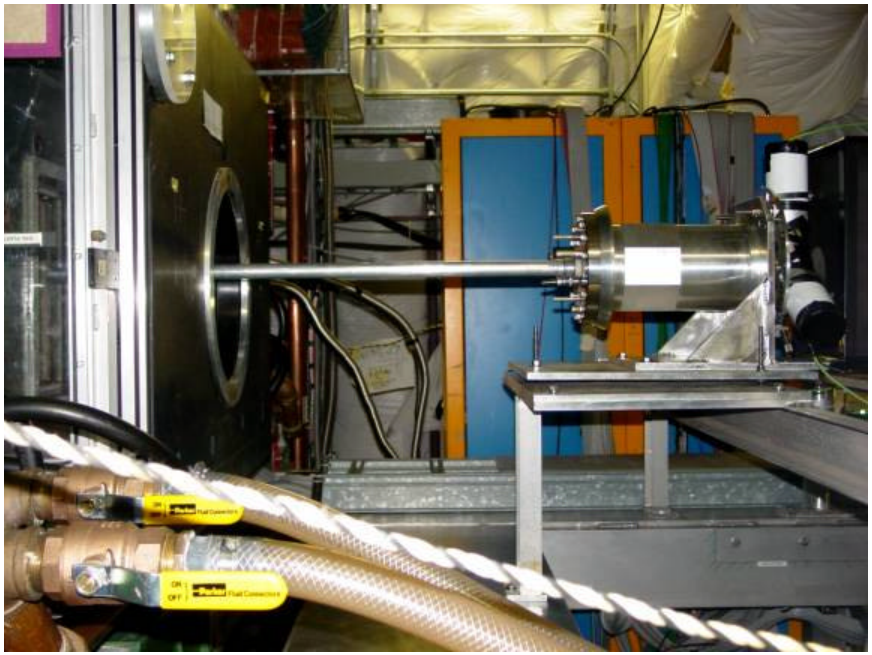
MIPP Particle ID

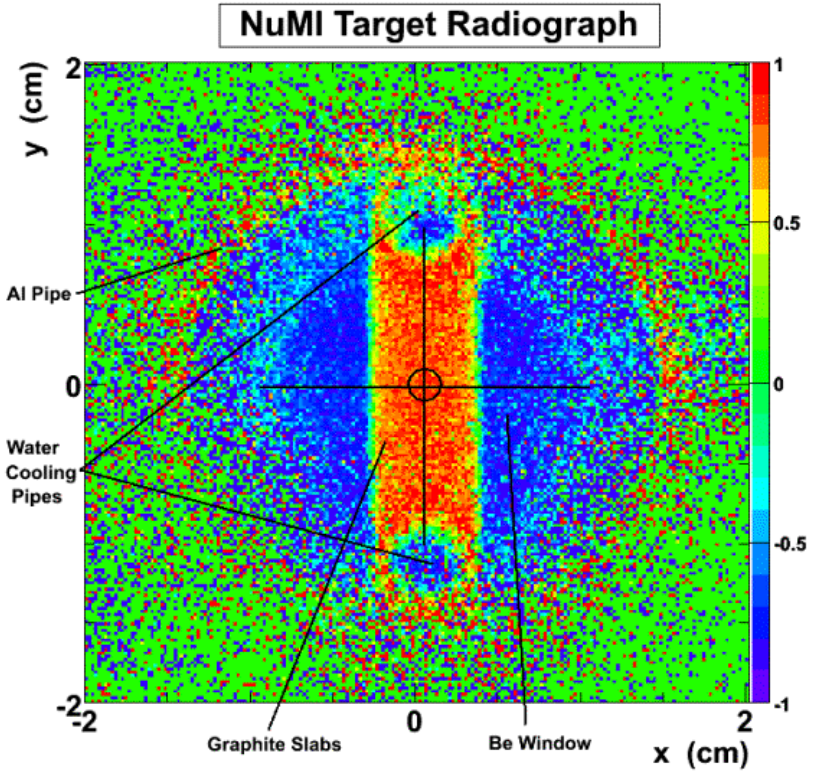
Particle ID Performance

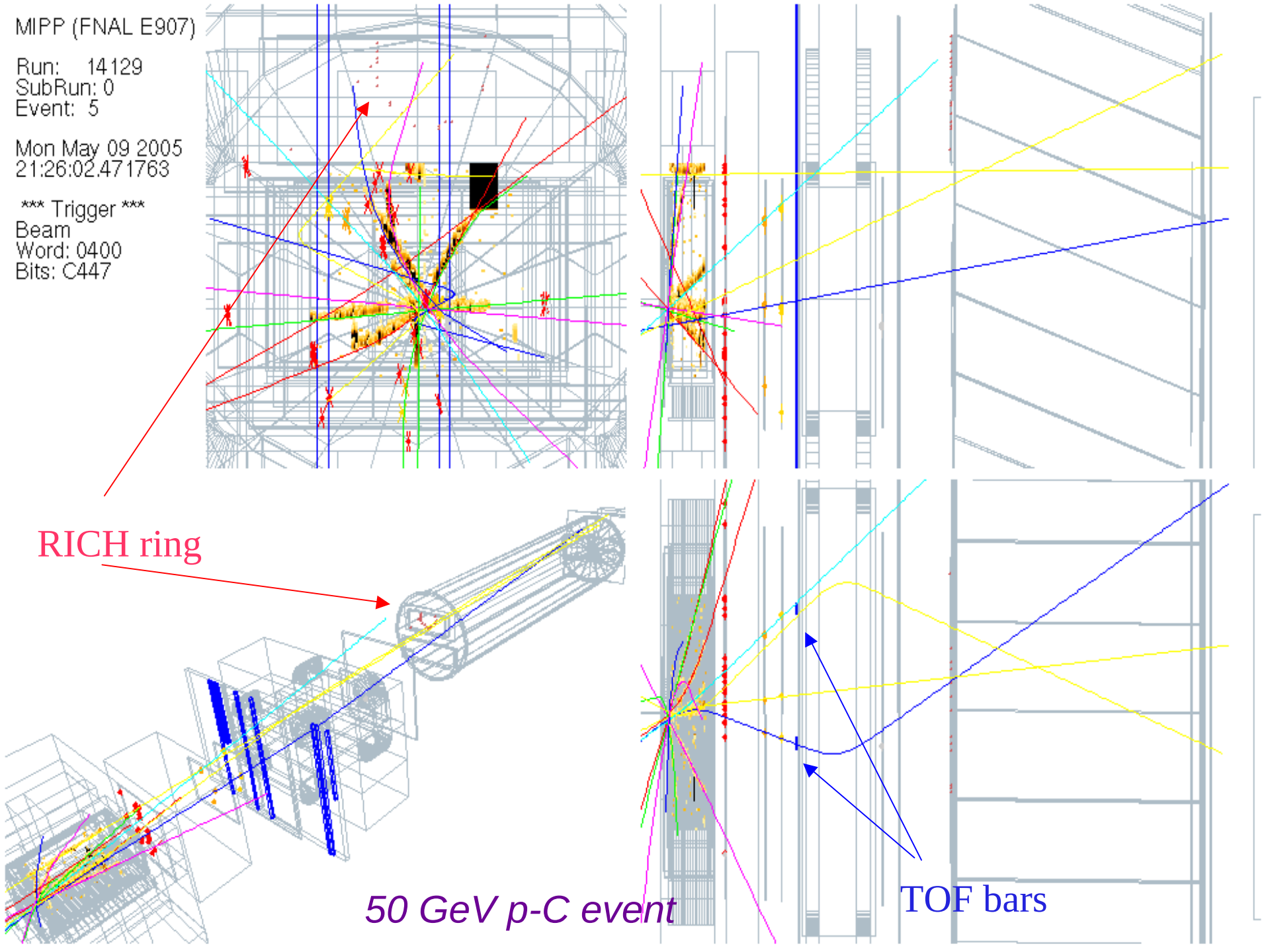


Red: >3 sigma
Green: 2-3 sigma
Blue: 1-2 sigma
White: <1 sigma

NUMI target pix

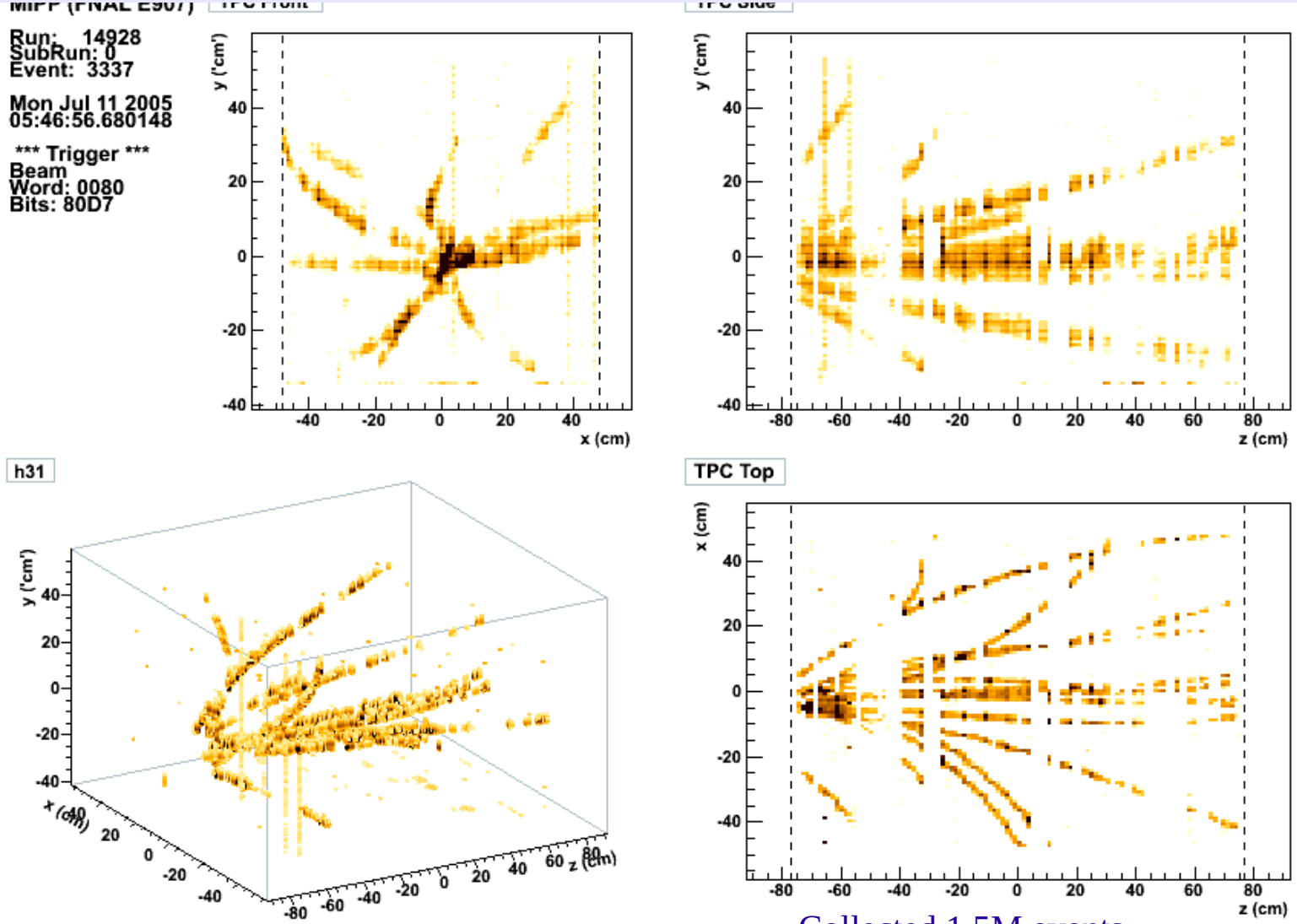






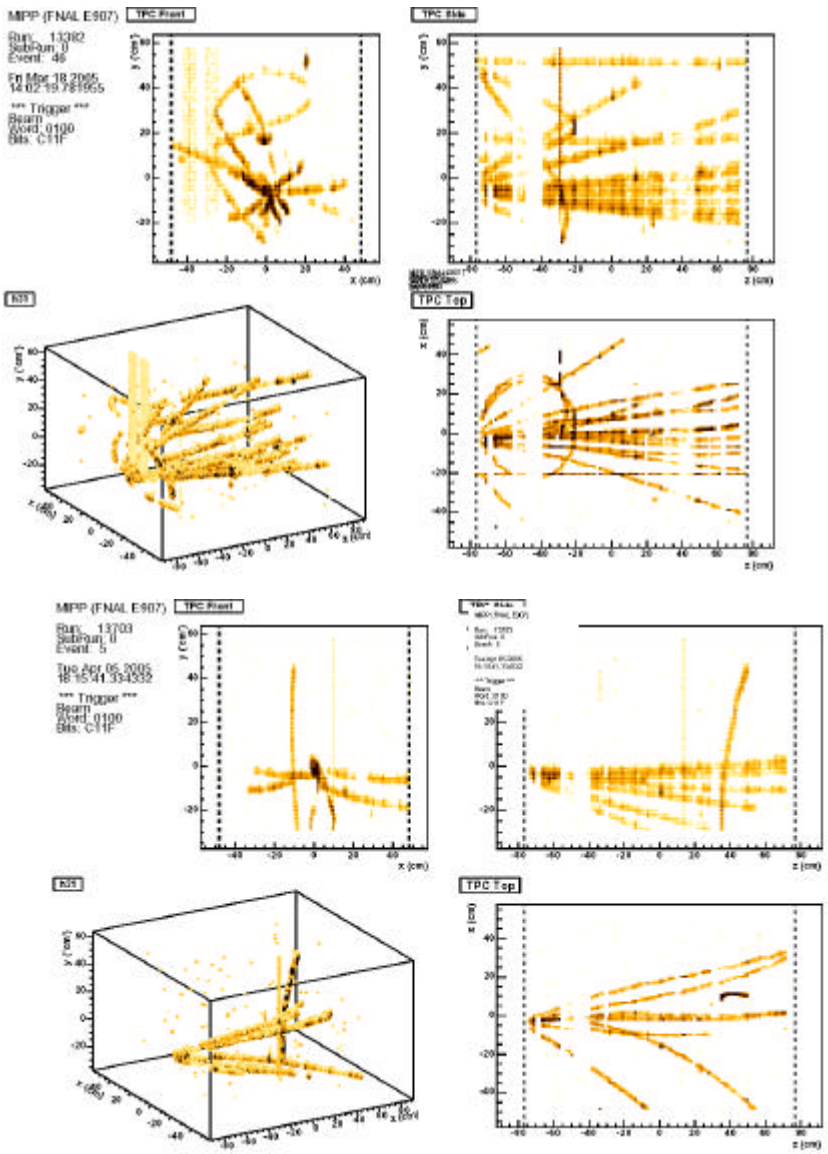
50 GeV p-C event

Sample Event On NuMI Target



- Collected 1.5M events
- NuMI target ran in July'05
- Target returned to NuMI

TPC events
50 GeV, -85 GeV cryo target(bottom)



First look at NuMI target data

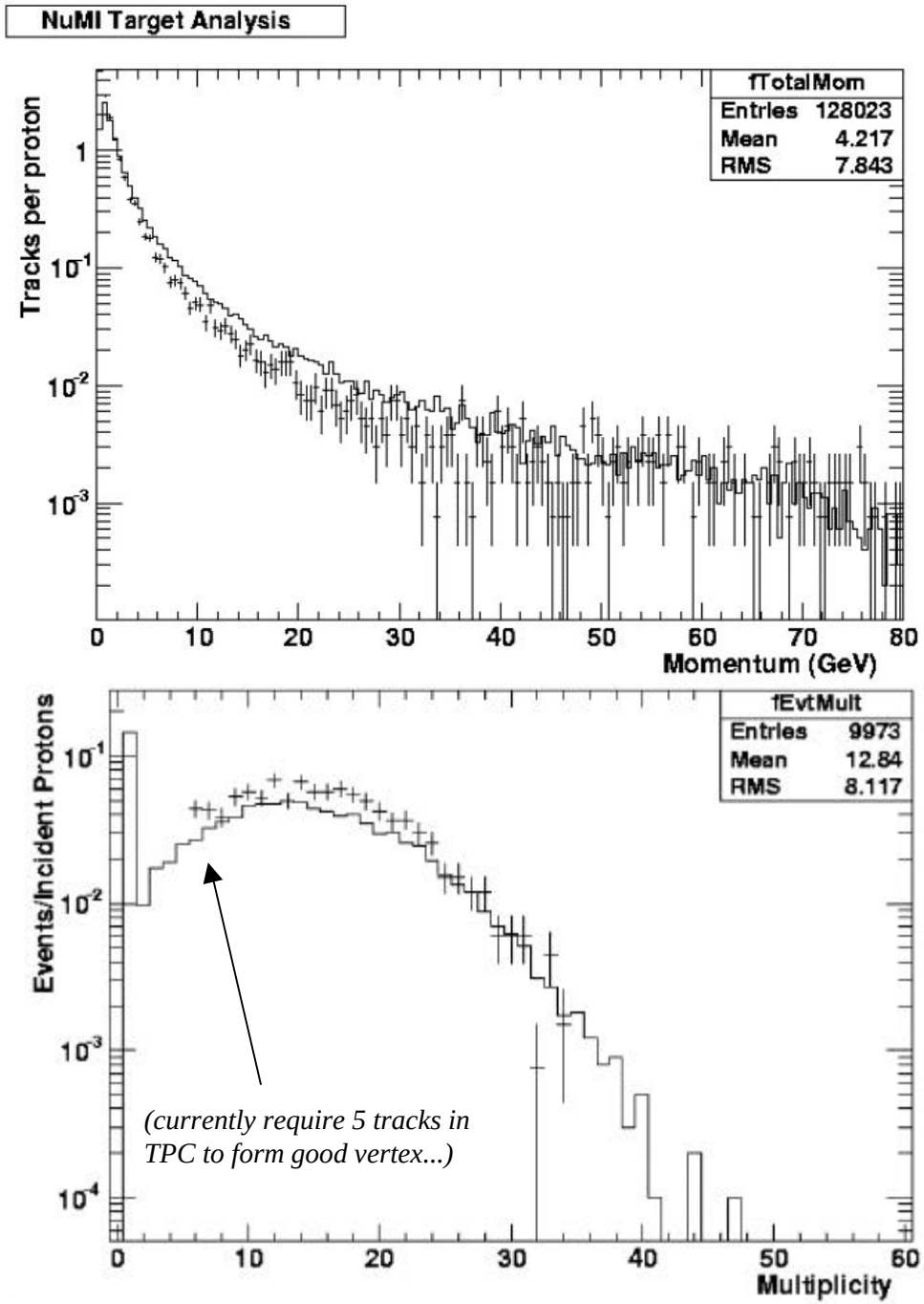
Very preliminary

Based on fast TPC-only helix fits

Comparisons are to FLUKA Monte Carlo

Top: Multiplicity distribution

Bottom: Momentum distribution



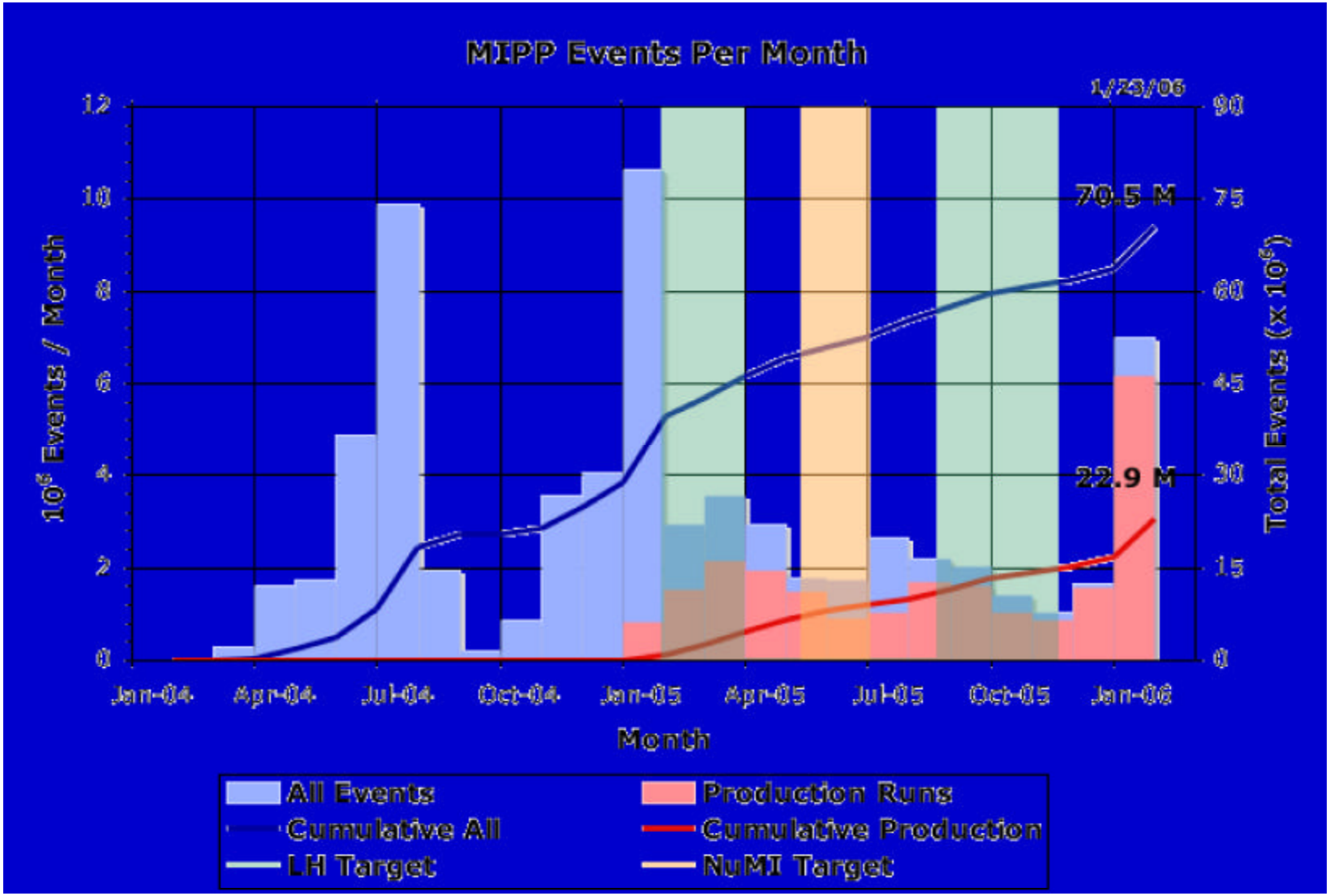
Physics of current Run

- Particle Physics-To acquire unbiased high statistics data with complete particle id coverage for hadron interactions.
  - » Study non-perturbative QCD hadron dynamics, scaling laws of particle production
  - » Investigate light meson spectroscopy, pentaquarks?, glueballs
- Nuclear Physics
  - » Investigate strangeness production in nuclei- RHIC connection
  - » Nuclear scaling
  - » Propagation of flavor through nuclei
- Service Measurements
  - » Atmospheric neutrinos – Cross sections of protons and pions on Nitrogen from 5 GeV- 120 GeV
  - » Improve shower models in MARS, Geant4
  - » Proton Radiography– Stockpile Stewardship- National Security
  - » MINOS target measurements – pion production measurements to control the near/far systematics
- Will make DST's available for the public on DVD's after we are done.
- HARP at CERN went from 2-15GeV incoming pion and proton beams. MIPP will go from 5-85 GeV/c for 6 beam species $\pi^{\pm}$ $K^{\pm}$ $p^{\pm}$ -- 420M triggers. 3KHZ TPC.

Data Taken So far (Till 23 Jan 06)

Data Summary 23 January 2006			Acquired Data by Target and Beam Energy Number of events, x 10^6							
Target			E							
Z	Element	Trigger Mix	0	5	20	35	45	60	85	120
0	Empty[1]				*0.10*	*0.14*	*0.03*	*4.39*		*0.25*
	K Mass							1.76		1.76
0	Empty LH[1]		0.01		*0.30*			*0.61*	*0.31*	
1	LH	Normal	0.03	0.21	**1.94**			**1.98**	**1.73**	
4	Be	*p* only								1.08
		Normal				0.10		0.56		
6	C	Mixed				*0.08*	0.08	**0.21**		**0.02**
	C 2%	Mixed			**0.39**			**0.26**		**0.47**
	NuMI	*p* only								**1.78**
13	Al	Normal				*0.10*	*0.01*	*0.02*		
29	Cu	Normal					*0.01*	*0.08*		
47	Ag	Normal					*0.07*			
83	Bi	*p* only								1.05
		Normal				0.52	0.02	1.23		
92	U	Normal	0.01					0.75		
Total			**1.81**	**0.21**	**2.73**	**0.98**	**0.20**	**10.11**	**2.04**	**4.76**

MIPP Run Statistics



LH2 data helps us study non-perturbative QCD. Why study non-perturbative QCD?

- Answer:- We do not know how to calculate a single cross section in non-perturbative QCD! This is >99% of the total QCD cross section. Perturbative QCD has made impressive progress. But it relies on structure functions for its calculations, which are non-perturbative and derived from data.
- Feynman scaling, KNO scaling, rapidity plateaus are all violated. We cannot predict elastic cross sections, diffractive cross sections, let alone inclusive or semi-inclusive processes. Regge "theory" is in fact a phenomenology whose predictions are flexible and can be easily altered by adding more trajectories.
- All existing data are old, low statistics with poor particle id.
- QCD theorist states- We have a theory of the strong interaction and it is quantum chromodynamics. Experimentalist asks– what does QCD predict? Almost as bad as the folks who claim string theory is the theory of everything! Experimentalist asks-what does it predict?

MIPP Physics Program

MIPP-I has 4 distinct clientele for its data, which are interconnected. They are

Liquid H2, D2 –non-perturbative QCD

p-A, p-rad (aka SURVEY)

NUMI thin and full target measurements

LN2– Atmospheric neutrinos

MIPP-Upgrade (100 times faster DAQ)will address missing hadron resonances problem using low energy beams (1-5 GeV/c)

Obtain higher statistics NUMI target data

Solve the hadron shower simulaton problem

Uses of MIPP QCD data

- Mostly will come from Liquid H2 target.
- We plan to take 18 million events on LH2 with 6 beam species ($\pi^{\pm}$,$K^{\pm}$,$p^{\pm}$)over a momentum range that spans 5 GeV/c to 90 GeV/c.
- We also plan to run Liquid deuterium (with upgraded MIPP), which will add np cross sections.
- We plan to re-open the study of non-perturbative QCD by publishing datasets with full particle ID in DST form in DVD's. Any person interested in testing his theory can obtain a dataset.
- We can study exclusive particle reactions with unprecedented accuracy and particle id using constrained fitting.

Uses of MIPP QCD data

- Examples of exclusive channels are

$\pi^+ p \to A_1(1270) p$	Resonance production and diffractio n
$\pi^+ p \to K^+ \Sigma^+$	Strangenes s production
$K^+ p \to pp\bar{\Lambda}$	strangenes s and Baryon number production
$K^+ p \to \Delta^+ K^0 \pi^+$	charge exchange and resonance production
$p^+ p \to ppK^+ K^-$	Difraction , strangenes s production
$p^+ p \to pp\pi^+ \pi^-$	Diffractiv e Dissociati on, Pomerons
$\pi^- p \to \pi^0 n$	Classic ρ exchange reaction
$\pi^- p \to K_*^0(892)\Lambda$	Strangenes s resonance production
$K^- p \to K_3^{*-}(1780) p$	Exotic resonance production
$K^- p \to pK^-$	Strange Baryon exchange
$p^- p \to 3\pi^+ 3\pi^-$	Annihilati on
$p^- p \to p\bar{n}\pi^-$	$\bar{p}$ diffractio n (4C if we detect $\bar{n}$, else 1C)

A more complete list of exclusive channels in all the beam species is available at

http://ppd.fnal.gov/experiments/e907/notes/MIPPnotes/public/pdf/MIPP0010/MIPP0010.pdf

Uses of MIPP QCD data

- Missing neutral channels are available as 1C fit.
- Diffraction in 6 beam species with particle id.
- Annihilation as a function of beam momentum
- Flavor propagation in nuclei $K^{\pm}$ propagating through nuclei. How fast is strangeness exchanged?
- Exotic resonances such as glueballs and pentaquarks(?) can be searched for. Unprecedented particle ID and acceptance capabilities as well as the presence of 6 beam species in one experiment will help unravel the nature of the found objects.
- Upgrading the TPC electronics will enable MIPP to take data at 1000HZ instead of the current 60HZ. This will enhance the physics potential of MIPP.

General scaling law of particle fragmentation

- States that the ratio of a semi-inclusive cross section to an inclusive cross section

$$\frac{f(a+b \rightarrow c+X_{subset})}{f(a+b \rightarrow c+X)} \equiv \frac{f_{subset}(M^2, s, t)}{f(M^2, s, t)} = b_{subset}(M^2)$$

- where M^2,s and t are the Mandelstam variables for the missing mass squared, CMS energy squared and the momentum transfer squared between the particles a and c. PRD18(1978)204.
- Using EHS data, we have tested and verified the law in 12 reactions (DPF92) but only at fixed s.
- The proposed experiment will test the law as a function of s and t for various particle types a ,b and c for beam energies between ~5 GeV/c and 120 GeV/c to unprecedented statistical and systematic accuracy in 36 reactions.

Estimation of the Annihilation component in pbar-p interactions

- R.Raja, Phys.Rev.D16:142,1977
- Conventional method is to subtract pp cross section from pbar-p cross sections. Works well for total cross section, and multiplicity cross sections. Works for neutral pion inclusive cross sections but FAILS for charged pion inclusive cross sections.

Estimation of the annihilation component

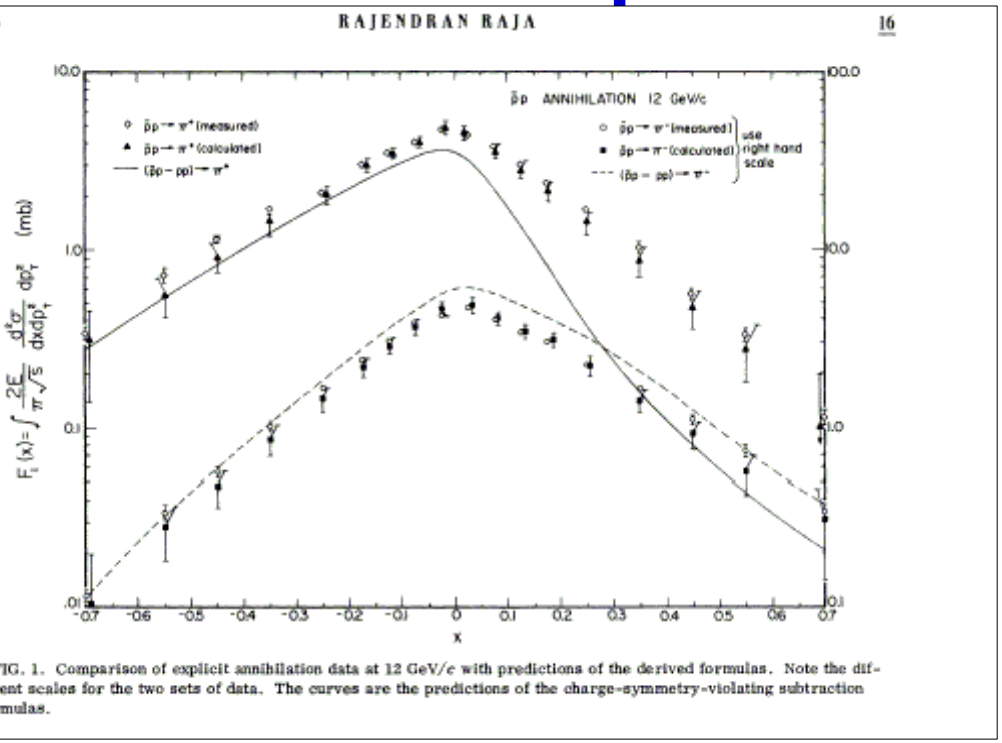


FIG. 1. Comparison of explicit annihilation data at 12 GeV/c with predictions of the derived formulas. Note the different scales for the two sets of data. The curves are the predictions of the charge-symmetry-violating subtraction formulas.

Estimation of the annihilation component

$\bar{p}p \to p^+ + X \equiv \bar{p}^+ \;;\; \bar{p}p \to p^- + X \equiv \bar{p}^-$

$\bar{p}p \to p^+ + X(ann.) \equiv \bar{p}_A{}^+ \;;\; \bar{p}p \to p^- + X(ann.) \equiv \bar{p}_A{}^-$

$pp \to p^+ + X \equiv p^+ \;;\; pp \to p^- + X \equiv p^-$

Denote by Π the Parity inversion operator

Then

$\Pi\bar{p}^+ = \bar{p}^-; \Pi\bar{p}^- = \bar{p}^+; \Pi p^+ = p^+; \Pi p^- = p^-$

$\Pi\bar{p}_A{}^+ = \bar{p}_A{}^-; \Pi\bar{p}_A{}^- = \bar{p}_A{}^+$

whereas for $p^{0's}$, both $\bar{p}p$ and pp are even under inversion.

- So π^0 production in annihilation information is available by subtraction

$$\bar{p}_A^0 = \bar{p}^0 - p^0$$

- but not $\pi^{\pm}$.

$\bar{p}_A^+ \neq \bar{p}^+ - p^+$ $\qquad$ $\bar{p}_A^- \neq \bar{p}^- - p^-$

Estimation of the annihilation component

- However, the sum of π^+ and π^- is even under inversion, so we can write

$$\bar{p}_A^+ + \bar{p}_A^- = (\bar{p}^+ + \bar{p}^-) - (p^+ + p^-)$$

- However, the term $\bar{p}_A^+ - \bar{p}_A^-$ is odd under parity inversion and cannot be obtained from pp data. An expression that can be written for the odd term that treats annihilation and non-annihilation symmetrically is

$$\frac{\bar{p}_A^+ - \bar{p}_A^-}{\bar{p}_A^+ + \bar{p}_A^-} = \frac{\bar{p}_N^+ - \bar{p}_N^-}{\bar{p}_N^+ + \bar{p}_N^-} = \frac{\bar{p}^+ - \bar{p}^-}{\bar{p}^+ + \bar{p}^-}$$

Estimation of the annihilation component

- This leads to

$$\overline{p}_A^+ = \left(\frac{(\overline{p}^+ + \overline{p}^-) - (p^+ + p^-)}{(\overline{p}^+ + \overline{p}^-)} \right) \overline{p}^+$$

- And
-

$$\overline{p}_A^- = \left(\frac{(\overline{p}^+ + \overline{p}^-) - (p^+ + p^-)}{(\overline{p}^+ + \overline{p}^-)} \right) \overline{p}^-$$

Explanation for the charge asymmetry relation

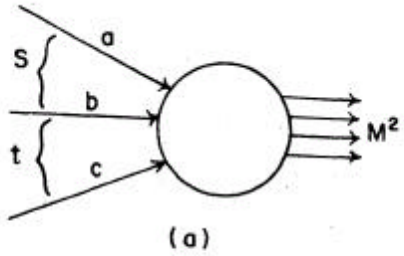
- See "Observation of New regularity in hadronic spectra", R.Raja Phys.Rev.D 18 (1978)204.
- The relation

$$\frac{\overline{p}_A^+ - \overline{p}_A^-}{\overline{p}_A^+ + \overline{p}_A^-} = \frac{\overline{p}_N^+ - \overline{p}_N^-}{\overline{p}_N^+ + \overline{p}_N^-} = \frac{\overline{p}^+ - \overline{p}^-}{\overline{p}^+ + \overline{p}^-}$$

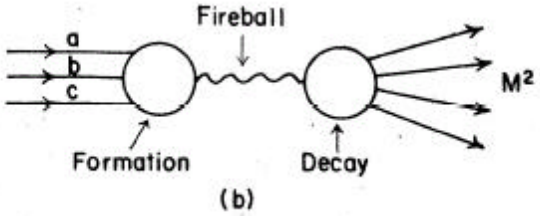
can be explained if one posits that the three body scattering happens in two steps. Formation of the fireball followed by its decay. Similar to the Bohr Compound nucleus hypothesis

Scaling Law

$$s\,(abc \to X) = F(M^2, s, t) D_X(M^2)$$
$$s\,(abc \to X_s) = F(M^2, s, t) D_{X_s}(M^2)$$



$$\frac{s\,(abc \to X_{sub})}{s\,(abc \to X)} = \frac{F(M^2, s, t) D_{X_{sub}}(M^2)}{F(M^2, s, t) D_X(M^2)} = a_{sub}(M^2)$$



$$\frac{f\,(ab \to \bar{c} + X_{sub})}{f\,(ab \to \bar{c} + X)} = a_{sub}(M^2)$$

- Continuing on to physical t values, one gets

Scaling law

- Applying to annihilations, one gets

$$\frac{\overline{p}_A^+(M^2,s,t)}{\overline{p}^+(M^2,s,t)} = a_A^+(M^2)$$

$$\frac{\overline{p}_A^-(M^2,s,t)}{\overline{p}^-(M^2,s,t)} = a_A^-(M^2)$$

$a_A^+(M^2) = a_A^-(M^2)$ due to C symmetry

leading to

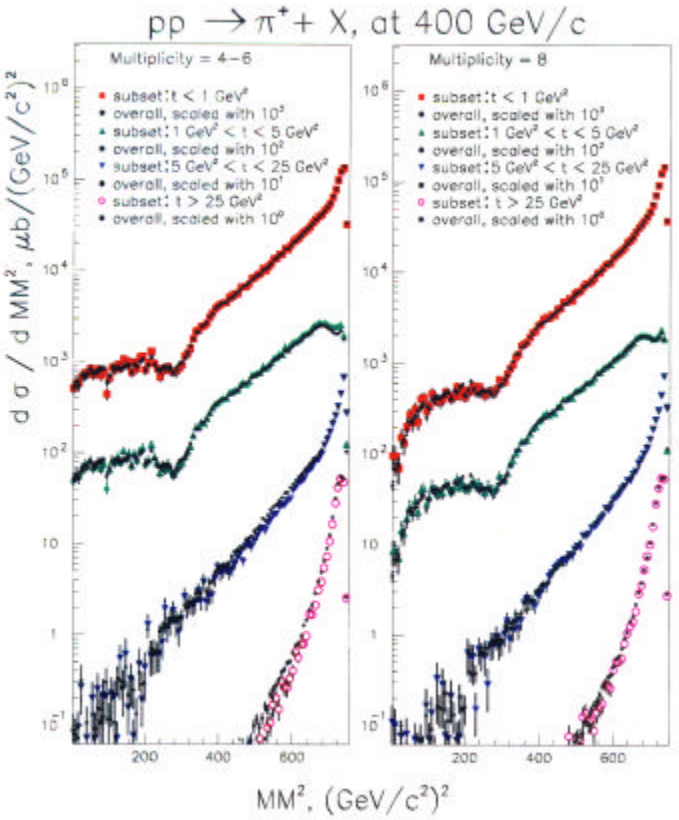
$$\frac{\overline{p}_A^+ - \overline{p}_A^-}{\overline{p}_A^+ + \overline{p}_A^-} = \frac{\overline{p}_N^+ - \overline{p}_N^-}{\overline{p}_N^+ + \overline{p}_N^-} = \frac{\overline{p}^+ - \overline{p}^-}{\overline{p}^+ + \overline{p}^-}$$

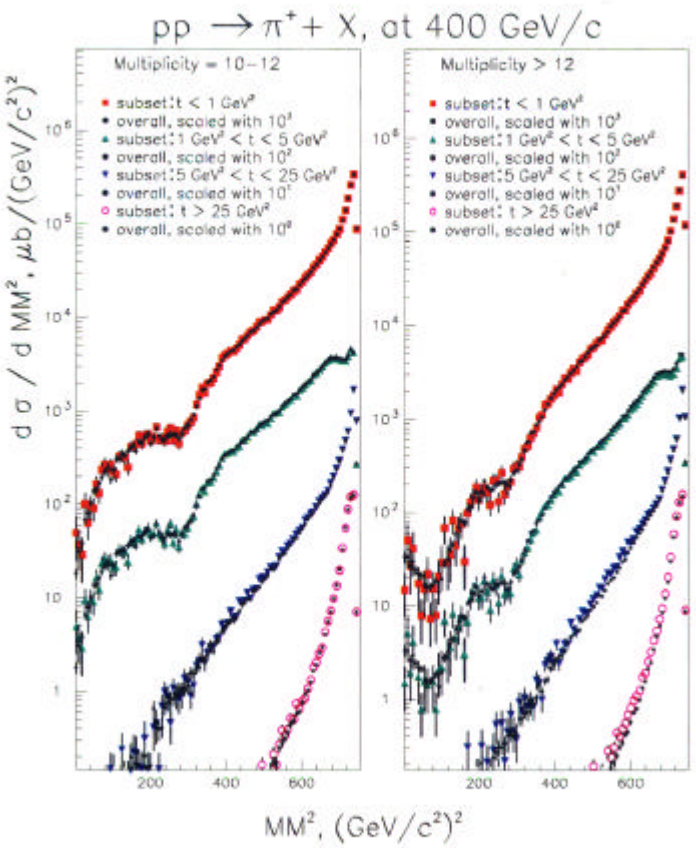
- This factorization and decay is general. So does it apply to other subsets? The answer is yes! Verified in 1978- Observation of a new regularity in hadronic spectra –RR- PRD18 204-209(1978)

More verification with European Hybrid Spectrometer data

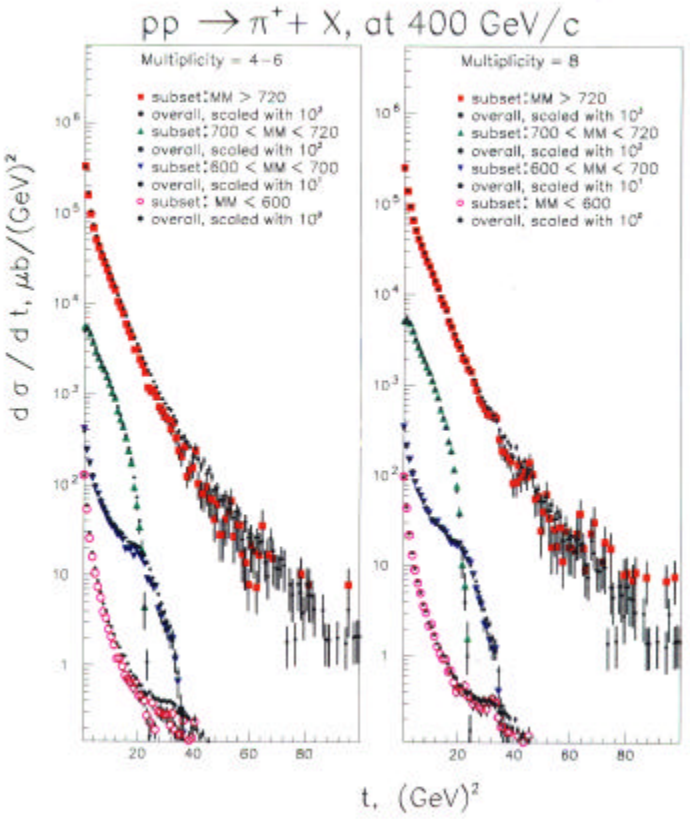
- 1 million events in EHS would have taken 3 years to analyze- Scan measure and track match. Incomplete particle id. Only data available at fixed s. Can test t independence.
- We have verified the scaling law in 12 reactions using EHS data at fixed s. (Y.Fisyak,R.Raja, Proceedings of the DPF1992 conference)

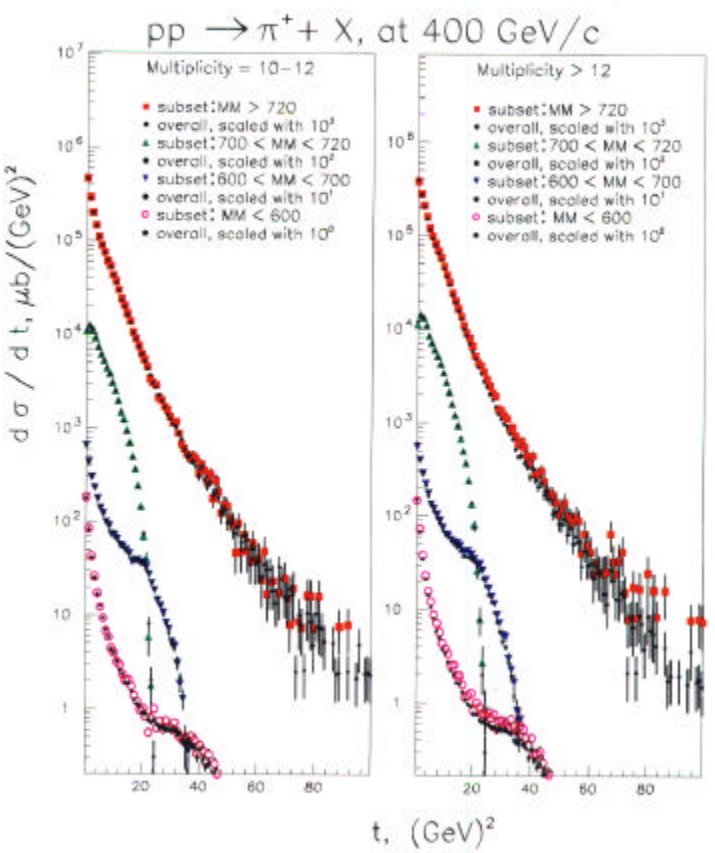
Scaling Law-EHS results





Scaling law -EHS results





Scaling Law tests with MIPP

- MIPP will test the scaling law with 36 reactions both in s and in t.

Positive Beam reactions

1	p^+	+	p	------->	p^+	+	X
2	p^+	+	p	------->	K^+	+	X
3	p^+	+	p	------->	p	+	X
4	p^+	+	p	------->	p^-	+	X
5	p^+	+	p	------->	K^-	+	X
6	p^+	+	p	------->	p^-	+	X
7	K^+	+	p	------->	p^+	+	X
8	K^+	+	p	------->	K^+	+	X
9	K^+	+	p	------->	p	+	X
10	K^+	+	p	------->	p^-	+	X
11	K^+	+	p	------->	K^-	+	X
12	K^+	+	p	------->	p^-	+	X
13	p	+	p	------->	p^+	+	X
14	p	+	p	------->	K^+	+	X
15	p	+	p	------->	p	+	X
16	p	+	p	------->	p^-	+	X
17	p	+	p	------->	K^-	+	X
18	p	+	p	------->	p^-	+	X

Negative Beam reactions

19	p^-	+	p	------->	p^+	+	X
20	p^-	+	p	------->	K^+	+	X
21	p^-	+	p	------->	p	+	X
22	p^-	+	p	------->	p^-	+	X
23	p^-	+	p	------->	K^-	+	X
24	p^-	+	p	------->	p^-	+	X
25	K^-	+	p	------->	p^+	+	X
26	K^-	+	p	------->	K^+	+	X
27	K^-	+	p	------->	p	+	X
28	K^-	+	p	------->	p^-	+	X
29	K^-	+	p	------->	K^-	+	X
30	K^-	+	p	------->	p^-	+	X
31	p^-	+	p	------->	p^+	+	X
32	p^-	+	p	------->	K^+	+	X
33	p^-	+	p	------->	p	+	X
34	p^-	+	p	------->	p^-	+	X
35	p^-	+	p	------->	K^-	+	X
36	p^-	+	p	------->	p^-	+	X

Among the 36, there are 15 crossing symmetry relations and 3 C symmetry relations

Scaling law tests with MIPP

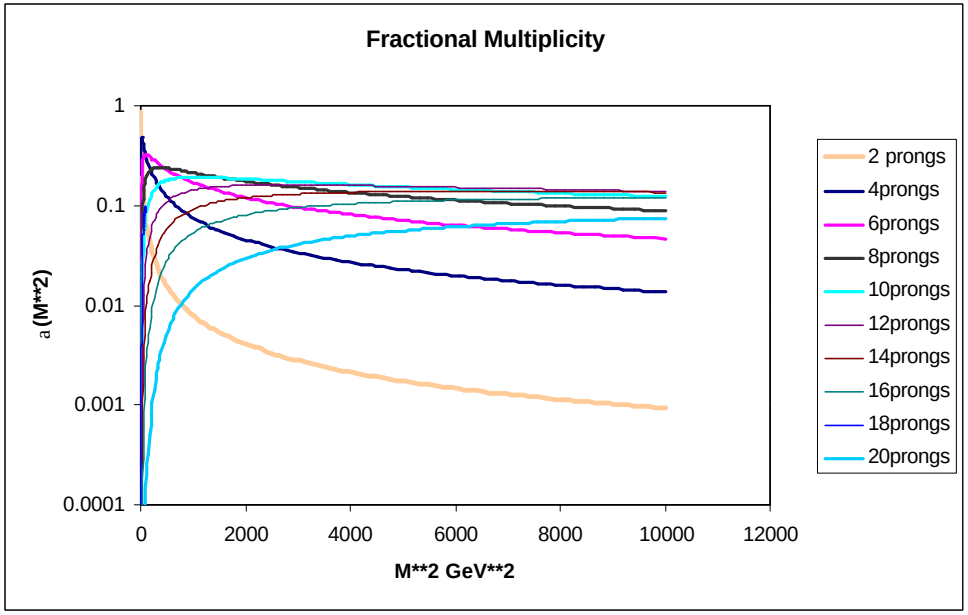
- For instance the functions $\alpha_s(M^2)$ by crossing symmetry must be the same for $\pi^+ p \rightarrow \pi^+ + X$ and $\pi^- p \rightarrow \pi^- + X$.
- Similarly

$$\bar{p}p \rightarrow p^+ + X \text{ and } p^- p \rightarrow p + X$$

Have the same $\alpha_s(M^2)$. So a diffractive process is linked to a central production process!

Scaling law tests with MIPP

These are the branching fractions of the fireball as a function of M^2. Central production reactions peak at x=0.



Since $x \approx 1 - \frac{M^2}{s}$, central production cross sections will move in the above plot with s. Diffraction cross sections will peak at small M^2 and will not change significantly with s.

Implications of the scaling law

- Semi-inclusive central production cross sections can show large s dependence. If $\alpha_{sub}(M^2)$ falls with M2, then that subset will fall with s and vice-versa. Central production subsets that fall with s will also exhibit a broader Feynman x distribution.
- Should extend this to see if 4 body scattering (two particle inclusive final state) and higher numbers exhibit similar behavior-Upgrade needed
- Can use scaling law to look for resonances. Scaling applies to a continuum of states that populate the cut in M^2 plane. If X is also a resonance in some subset, then interference will occur between signal and background for that mass range and will result in deviations from scaling. This can be used to look for resonances. E.g A1.

Better Charged Kaon Mass –PDG as of now

- Measured using X-ray emission from K-mesic atoms. K^- mass. K^+ and K^- masses also seem to disagree. 60 KeV difference between 2 major expts. Important for V_{us}

THE CHARGED KAON MASS

Revised 1994 by T.G. Trippe (LBNL).

The main disagreement is between the two most recent and precise results,

$$m_{K^\pm} = 493.696 \pm 0.007 \text{ MeV} \qquad \text{DENISOV 91}$$

$$m_{K^\pm} = 493.636 \pm 0.011 \text{ MeV (S = 1.5)} \qquad \text{GALL 88}$$

$$\text{Average} = 493.679 \pm 0.006 \text{ MeV}$$

$$\chi^2 = 21.2 \text{ for 1 D.F., Prob.} = 0.0004\% , \quad (3)$$

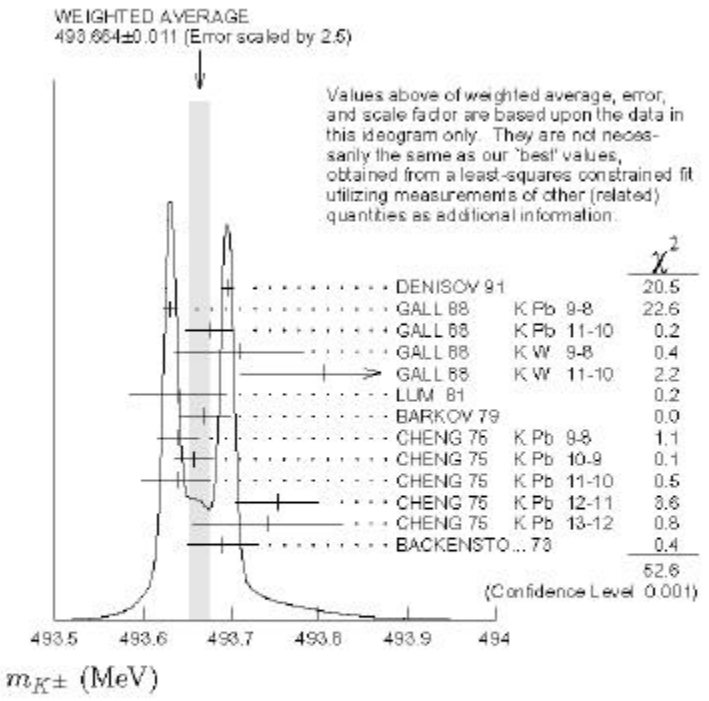


Figure 1: Ideogram of $m_{K^\pm}$ mass measurements. GALL 88 and CHENG 75 measurements are shown separately for each transition they measured.

Kaon Mass-MIPP projections

- Both charged Kaons can be measured. Upgrade will help this further

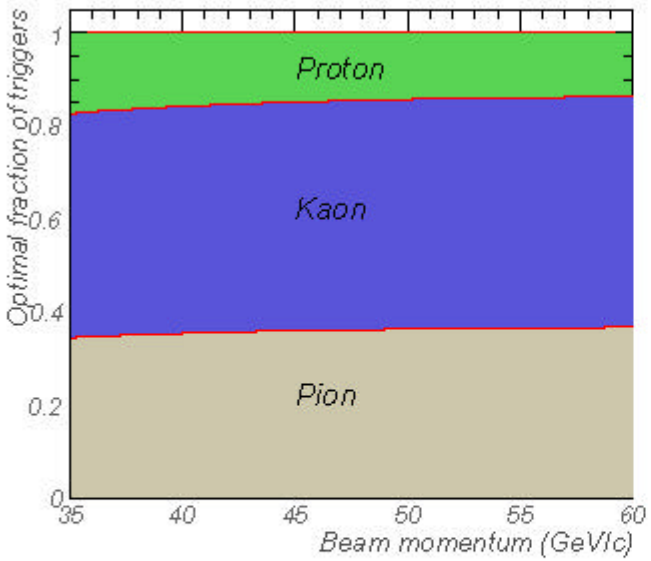


Figure 1: Optimal fraction of pion, kaon, and proton triggers (left), and expected statistical error for different total number of triggers, assuming optimal distribution of events in the sample (right).

Kaon data taken so far

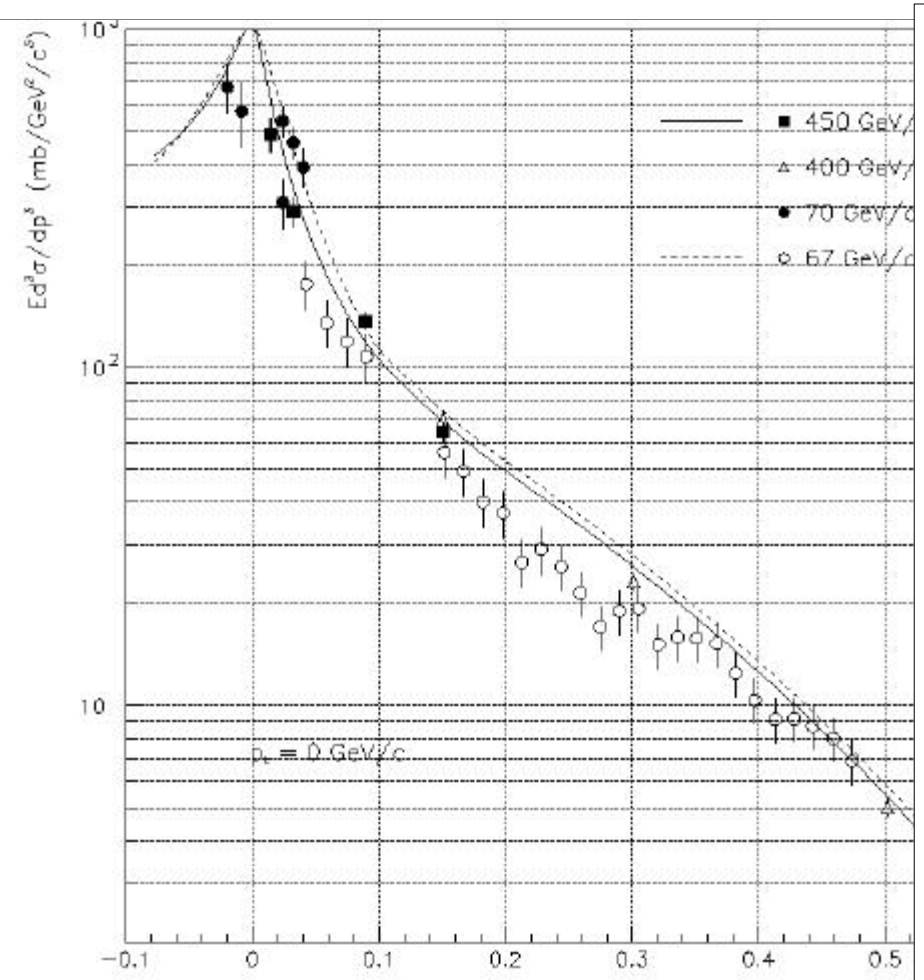
- Switch off TPC. Speed up DAQ ~300HZ.
- Lost JGG. In dedicated Kaon mode at +40 GeV. Can expect ~12Million events by end of run. Statistics to date--

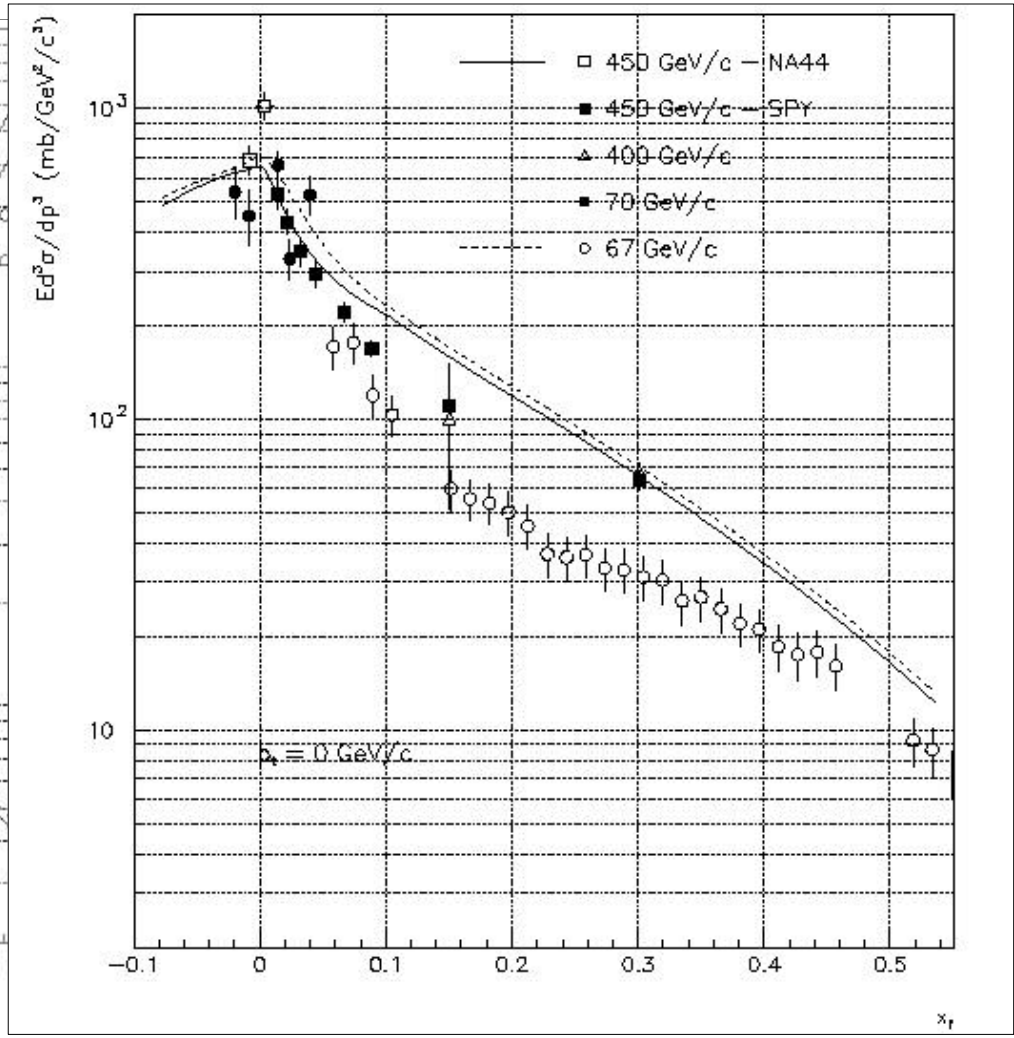
Momentum	JGG Field	Events
-60	0	2701458
40	0	964547
56	6.91	497633
59	0	2735482
59	6.91	738983
60	6.91	1212856
63	6.91	957474
		9808433

Hadron Shower Simulator problem

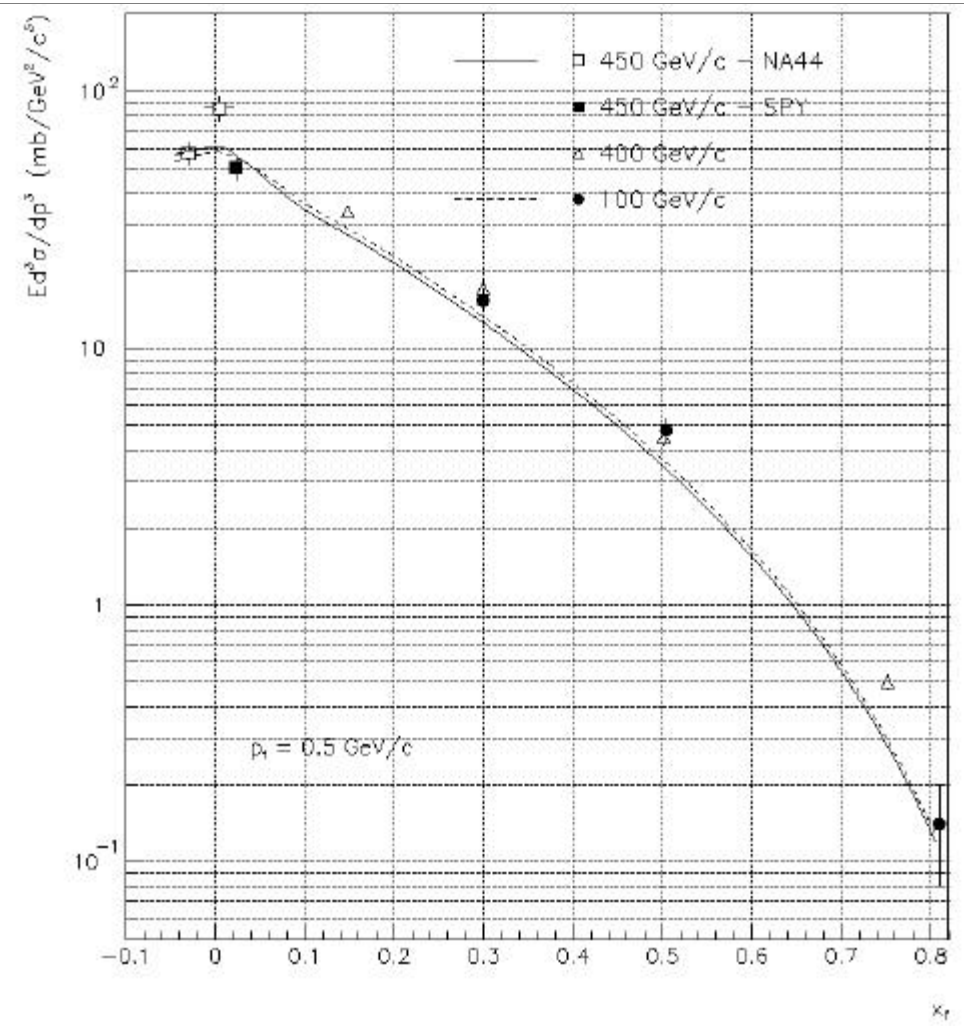
- All neutrino flux problems (NUMI, MiniBoone, K2K, T2K,Nova, Minerva) and all Calorimeter design problems and all Jet energy scale systematics (not including jet definition ambiguities here) can be reduced to one problem- the sorry state of hadronic shower simulators. MIPP upgrade can solve this problem for once and for all.
- Timely completion of MIPP upgrade progam can help CDF/D0 systematics, CMS/ATLAS, CALICE and all neutrino experiments.
- Myth-I Put designed calorimeter in test beam and use the data to tune the simulator_-D0 experience. You need test beam to test the hardware.
- Myth-II Take test beam data at various incident angles and use it to interpolate –H-matrix experience
- In order to have better simulator, we need to measure event by event data with excellent particle ID using 6 beam species (pi,K,P and antiparticles) off various nuclei (LH2 critical) at momenta ranging from 1 GeV/c to ~100 GeV/c. MIPP upgrade is well positioned to obtain this data.
- MIPP can help with the nuclear slow neutron problem.
- Current simulators use a lot of „Tuned theory". Propose using real library of events and interpolation.

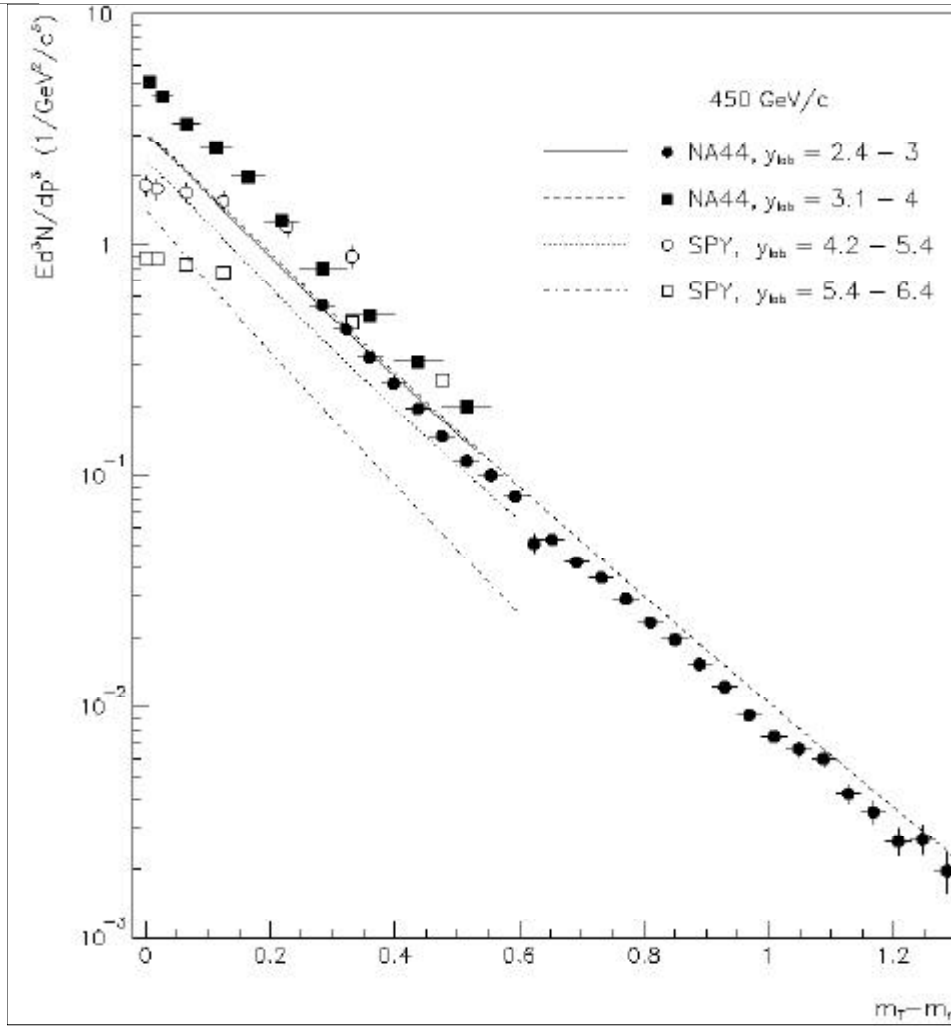
Quality of existing data





Quality of existing data



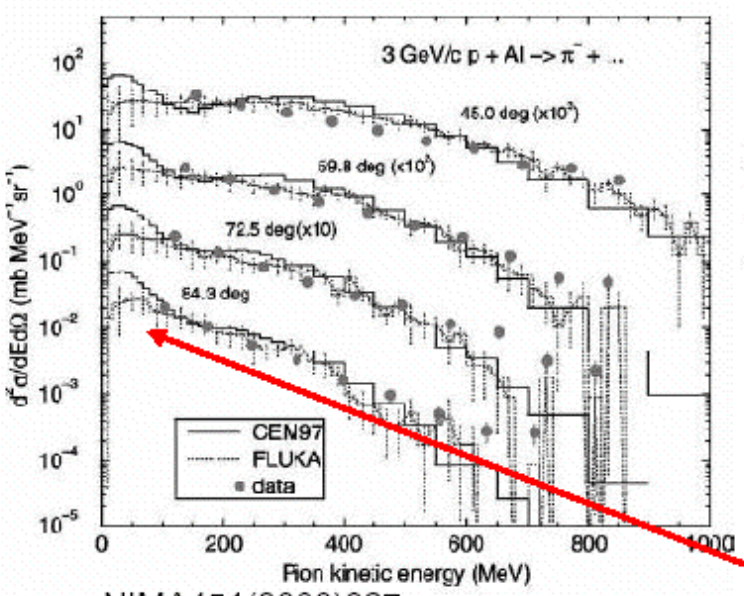


Discrepancies between hadronic generators

Lack of experimental data and large uncertainties in the calculations,

in particular for thick and high Z target materials

Differential distributions for pion production:



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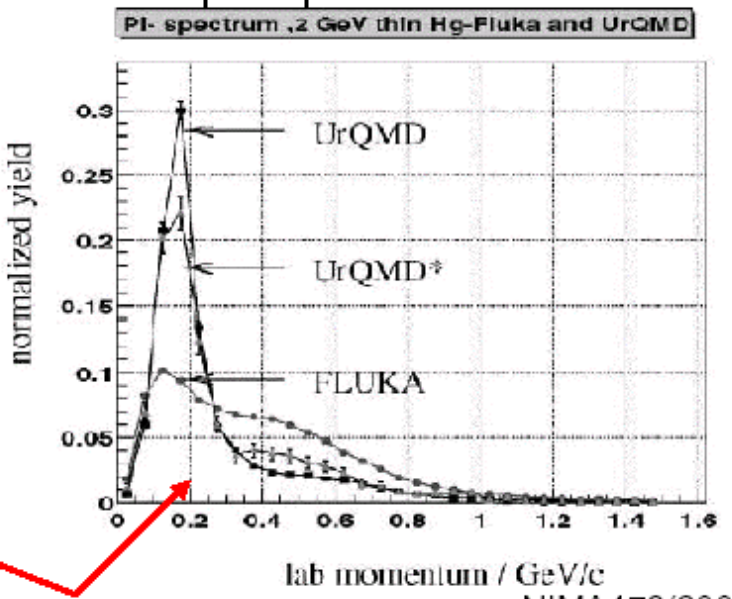

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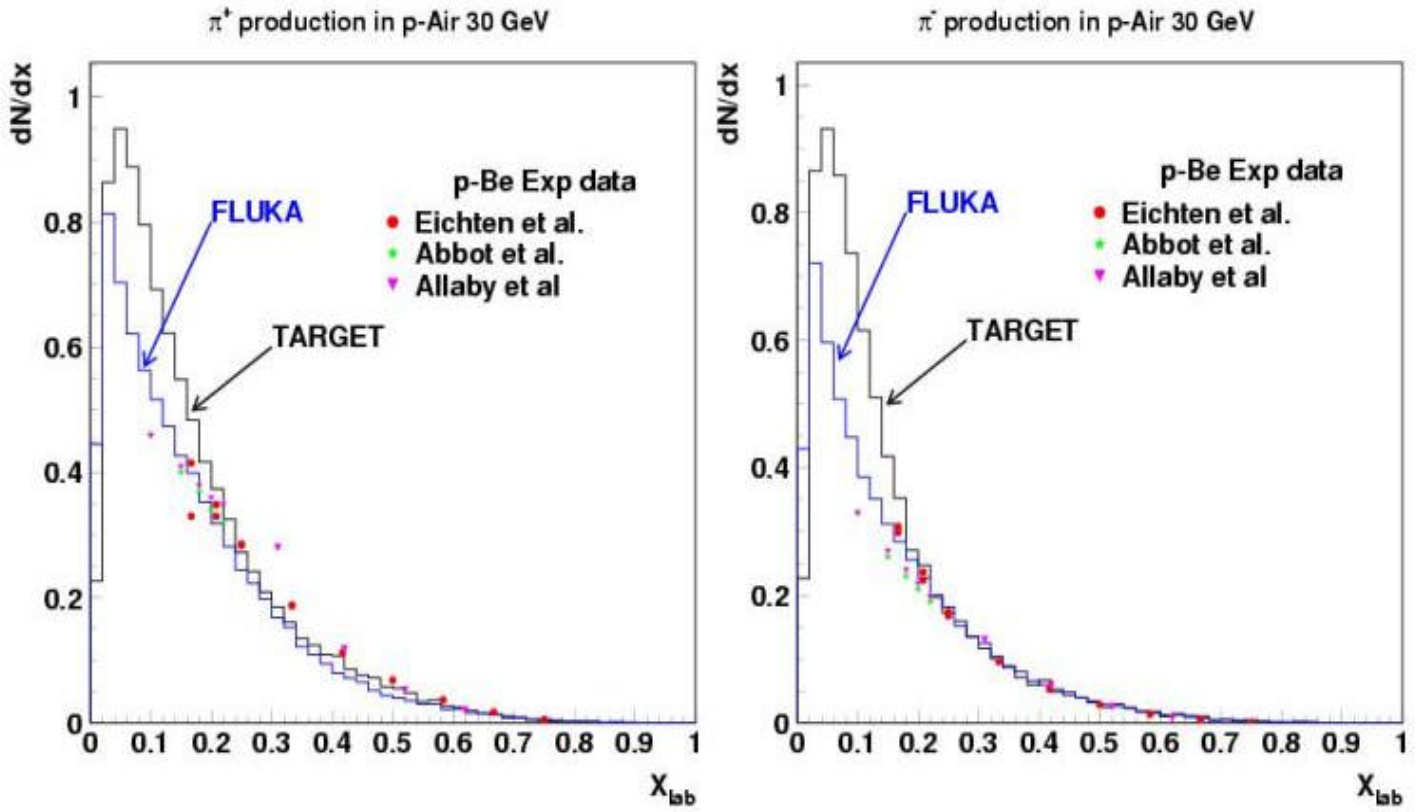
NO DATA !

➔ Thin and thick targets, scan in Z

Discrepancies between hadronic generators



G.Battistoni

MIPP Upgrade program

- Speed up TPC DAQ by using ALICE ALTRO/PASA chips. We have ben given he green light to acquire these chips from CERN ($80K).
- Speed up rest of DAQ.
- Is important for

  CDF/D0, CMS/Atlas (hadronic Energy scale)

  PIERRE AUGER/ICE CUBE(hadronic Energy scale)

  Super K/Hyper K (Neurino Spectra)

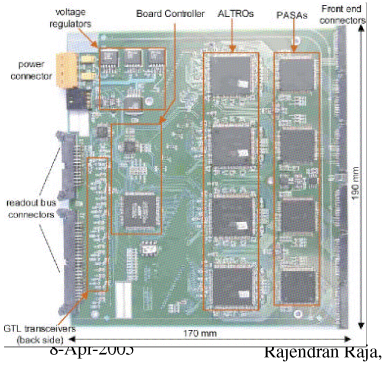
  MINOS/MINERvA/NOvA. (Neutrino spectra)

  CALICE (hadronic energy scale/resolutions)

ALICE Chips

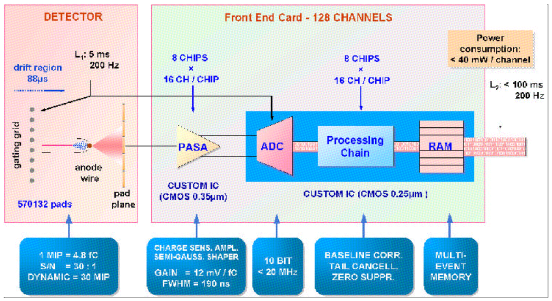
ALICE PASA/ALTRO Chip

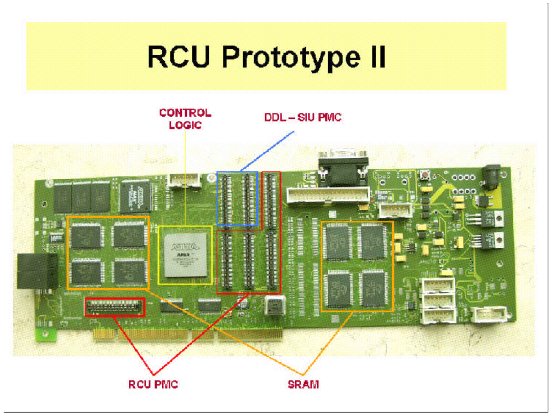
- PASA-Preamp/Pulse shaper One chip=16 pads.
- ALTRO-Digitizes,memory buffer. Controlled by ALTRO bus (40bits wide) with a Readout Control Unit.
- Thoroughly debugged and tested for ALICE. Needed by STAR, TOTEM, MIPP and being used by BONUS.



ALICE Front end card needs to be rearranged to look like a stick.

ALTRO/PASA chips





Upgrade Rest of DAQ

Upgrading the DAQ of the rest of MIPP to run at 3kHz.

- RICH and Hadron Calorimeter-Will work as is
- EM Cal- Use Lacroy FERA ADC's from Prep.
- Proportional Chambers-Use Hyper CP electronics-5000 channels
- Multi Cell Cerenkov-Use FERA bus to readout the 96 channels faster.
- Time of Flight system-~100 channels. Zero suppress, FERA bus.
- Drift chambers-7808 channels for drift chambers and 1920 for beam chambers.-CDF or KTEV electronics
- DAQ software-Improve interrupt handling,Write better VME drivers, Make use of DMA on the VME bus.

Jolly Green Giant Coil Fix

- One of the bottom coils has developed shorts. We are running with several turns shorted out. After the October shutdown, we propose to fix the coil.

Labor and costs in repairing the JGG coil

Equipment	Action	Manpower	Manweeks	M&S
BCKOV				
	secure & disconnect vacuum	2 techs, 2 weeks	4	
	re-install vacuum & test	3 techs, 3 weeks	9	
	remove cable tray & hardline	2 techs, 1 week	2	
	re-install cable tray & hardline	3 techs, 2 weeks	6	
	M&S purchases	$2K		$2,000
Beam pipe				
& concrete supports	move to side	4 techs, 1 week	4	
	re-install	4 techs, 2 weeks	8	
LH2 Target	Move LH2 target equipment out	2 techs 1 week	2	
TPC				
	De-cable	By experimenters		
	Re-cable	By experimenters		
	remove electrical conduit	M&S $4K		$4,000
	re-install electricalconduit	M&S $8K		$8,000
	move out TPC & support st&	3 techs, 1 week	3	
	re-install TPC & support st&	3 techs, 1 week	3	
JGG				
	de-cable	2 techs, 2 days		
	re-cable	2 techs, 3 days	1	
	de-hose	1 tech, 1 day		
	re-hose	1 tech, 4 days	1	
	remove coil	M&S $15K	1	$15,000
	install coil	M&S $6K	1	$6,000
Repair JGG coil				
	M&S	$90K		$90,000
	OH	$20K		$20,000
	total man-weeks		45	
	total M&S			**$145,000**

- Optional Upgrades

Cryogenic target -Extra cryo cooler	$32,000
TPC Rewind (M&S)	$10,000
RICH phototube upgrade (Hamamatsu tubes, bases)	$204,000

Total Running time requested

Physics Topic	Run Time (d
MIPP -I	18.1 days
New neutrino experiment target (10 million events)	2.3 days
Additional Nucleus (5 million events)	1.15 days
Two particle inclusive scaling (100 million events)	23.1 days
Pentaquark search (K+ beam)	12 days
Cascades search (K- beam)	15 days
Missing baryon search using low momentum pions	82 days

Proposal to upgrade the TPC DAQ speed

- The MIPP TPC electronics if 1990's vintage. It is highly multiplexed and can run at a maximum of 60HZ for simple events and 20Hz for events of our complexity. There are 15,360 channels on the TPC.
- With more modern electronics (those developed for the ALICE collaboration at the LHC (PASA/ALTRO), we can speed this rate up to 3000HZ. I.e. a factor of 150.
- We propose to join a chip order along with STAR and TOTEM collaborations (this MAY). This will reduce the cost by (sharing the overhead) to ~$8/channel.
- With this upgrade (and the rest of the systems can also be upgraded to run at 3KHZ), and assuming one 4 second spill every 2 minutes and a 50% duty factor,

MIPP upgraded data taking times

- The entire MIPP I (current run, approved physics)dataset (75 million events) can be acquired in 18.1 calendar days!
- We can also do additional physics which I will describe.
- This has brought in new collaborators, several (4) signing the proposal and several more institutions expressing strong interest.

Nuclei of interest- 1st pass list

- The A-List
- H_2,D_2,Li,Be,B,C,N_2,O_2,Mg,Al,Si,P,S,Ar,K,Ca,,Fe,Ni,Cu,Zn,Nb,Ag,Sn,W,Pt,Au,Hg,Pb,Bi,U
- The B-List
- Na, Ti,V, Cr,Mn,Mo,I, Cd, Cs, Ba
- On each nucleus, we can acquire 5 million events/day with one 4sec beam spill every 2 mins and a 50% downtime.
- We plan to run several different momenta and both charges.
- The libraries of events thus produced will be fed into shower generator programs which currently have 30 year old single arm spectrometer data with high systematics

Additional Physics with upgraded MIPP

- Non-Perturbative QCD
  - » Test scaling in two particle inclusives- More variables. Need more statistics.
- More nuclei can be measured
- Future Neutrino experimental targets- FINESSE, T2K
- Low Momentum Pion and Kaon Physics. Pion beams of 1 GeV/c and Kaon beams of 5 GeV/c and greater are possible.
- With 1GeV/c-5GeV/c beams, missing baryon physics becomes doable. Coupled channel partial wave analyses.

Missing baryon Resonances

- Low momentum pions (<5 GeV/c) need new power supplies that regulate at such low currents. J.Lentz proposes using trim element supplies (plentiful at the lab) and switching between the two sets as running conditions demand.
- Partial wave analyses of πN scattering have yielded some of the most reliable information of masses, total widths and πN branching fractions. In order to determine couplings to other channels, it is necessary to study inelastics such as

$$p^- p \to hn; p^- p \to p^+ p^- n; p^- p \to K^0 \Lambda$$

$$gp \to p^0 p; gp \to K^+ \Lambda; gp \to p^+ p^- p$$

- All of the known baryon resonances can be described by quark-diquark states. Quark models predict a much richer spectrum. Where are the missing resonances?

Missing Baryon Resonances

- A)They do not exist
- B)not been seen because they couple weakly to πN channel. So look for them in (J-Lab) $gp \rightarrow K^{+}\Lambda$
- If you find any, then one would like to determine the state's helicity amplitudes in order to make comparisons to quark model predictions. To do this, you need high statistics data in πN elastics and $pN \rightarrow K\Lambda$ (MIPP)

Such data do NOT exist and MIPP can provide this if upgraded.

Missing Baryon Resonances

- Resonances fall into four well defined regions.
  - » $P_{33}(1232)$ region
  - » c.m energy ~1.5GeV $P_{11}(1440)$/Roper Resonance, $D_{13}(1520)$,$S_{11}(1535)$
  - » c.m. energy of 1.7GeV Nine resonances $S_{11}(1650)$,$D_{15}(1675)$,$F_{15}(1680)$,$D_{33}(1700)$, $P_{11}(1710)$,$P_{33}(1600)$,$S_{31}(1620)$,$D_{33}(1700)$
  - » c.m.energy 1.9-2.0GeV. Includes contributions from 7 resonances, most importantly $F_{37}(1950)$. There are approximately nine missing positive-parity resonances in this N=2 band.
- Not much is known above this region. One expects the region near 2.2 GeV to be populated by several N=3 negative parity states and some N=4. MIPP upgrade can explore these regions.

Missing Baryon Resonances

- Reactions which permit coupled channel partial wave analyses but which need much higher statistics.

pN elastic scattering

$p^- p \rightarrow p^- p^0 p$ (detect p^0 by MM)

$p^+ p \rightarrow p^+ p^0 p$ (detect p^0 by MM)

$p^- p \rightarrow p^+ p^- n$ (detect n by MM)

$p^+ p \rightarrow p^+ p^+ n$ (detect n by MM)

- Entire data set for above consist of 241,000 events. Above 1600 MeV PWA becomes noisy, due to low statistics. MIPP will produce an order of magnitude more statistics

F.Wilczek working on this problem.

- -------- Original Message --------
  Subject: Re: [Fwd: Information on the MIPP experiment]
  Date: Fri, 21 Oct 2005 15:51:02 -0400
  From: Frank Wilczek <wilczek@MIT.EDU>
  To: Rajendran Raja <raja@fnal.gov>
  CC: SELEM, ALEXANDER <aselem@calmail.berkeley.edu>, gross@itp.ucsb.edu
  References: <43594054.9020201@fnal.gov>

  Hi,

  I find it very interesting.

  Pursuing some ideas on diquarks (with Alex Selem) led us into a broad survey of hadron spectroscopy. That emphasized two things for me:

  1. There are some strikingly simple patterns in the data that are poorly understood from the point of view of QCD.

  2. There are many holes in the data, if these patterns are not misleading us. In other words, there are lots of predictions to be tested, and refined.

  We're in the process of writing this up, but in the meantime I've attached my presentation (in keynote and .pdf) which should give you some idea what's coming. I hope you find it useful.

  All best wishes,
  Frank Wilczek

Missing baryon Resonances

- Strangeness production

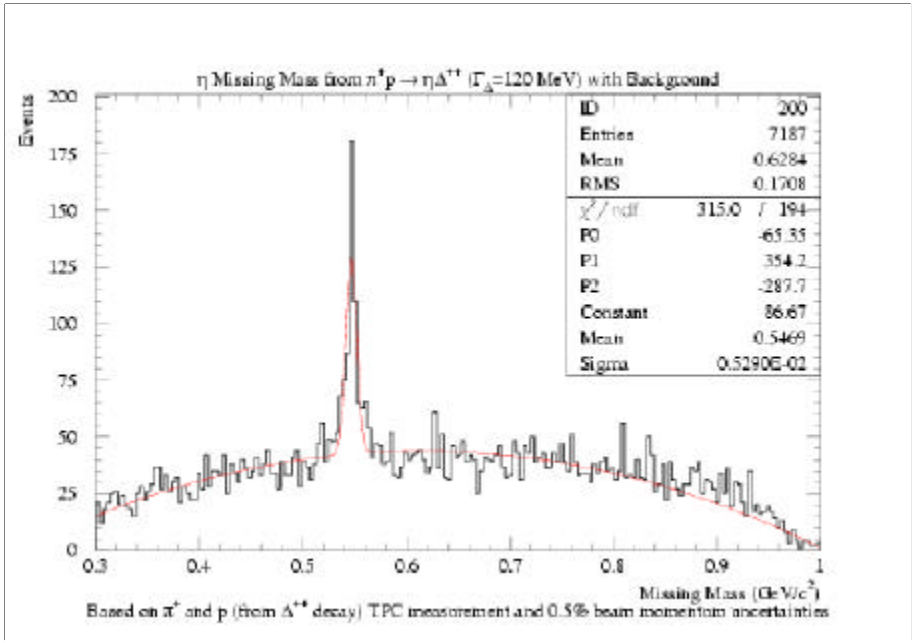
$p^- p \to K^0 \Lambda$ (Pure I = 1/2 reaction)

$p^- p \to K^0 \Sigma^0; \Sigma^0 \to \Lambda g$ (g by MM)

$h\Delta$ and $w\Delta$ resonances (I = 3/2)

$p^+ p \to h p^+ p$ (h by MM)

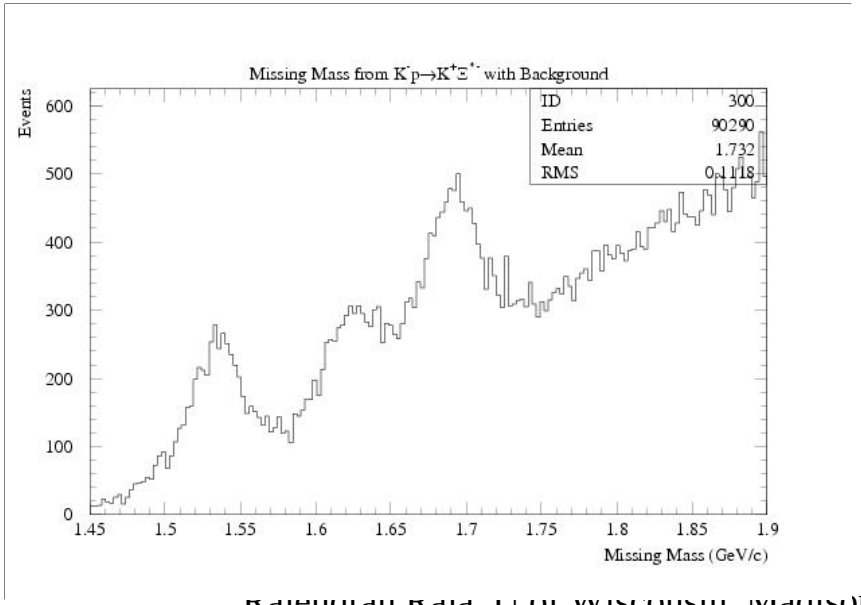
$p^+ p \to p^+ w p$



Missing Cascade Resonances

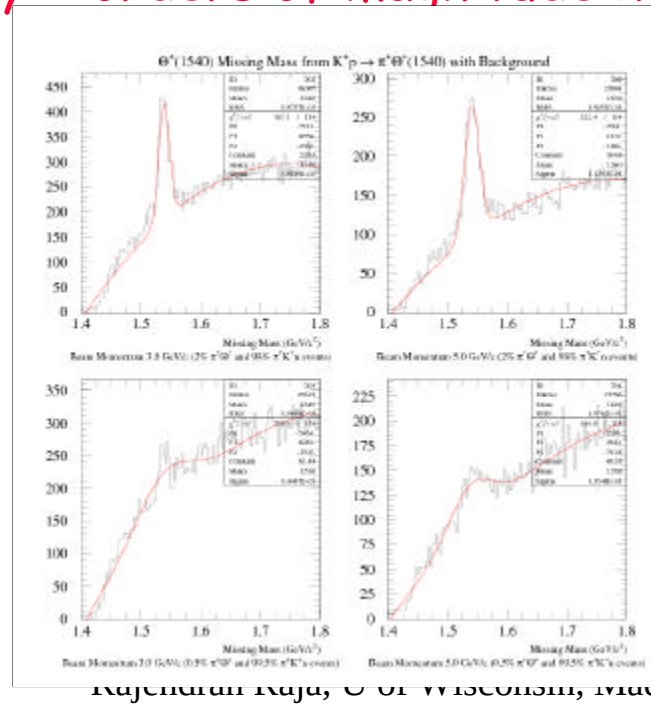
- Similar situation here-
- PDG " Not much is known about Cascade resonances…"
- There are 11 Ξ resonances (including ground state listed in PDG), 44 are predicted. 5 GeV/c Kaons.

$$K^- p \rightarrow K^+ \Xi^*$$



Pentaquarks

- Pentaquarks are "controversial". Several experiments claim to see them and several others do not. MIPP can look at the channel $K^+ p \rightarrow p^+ q^+$
- MIPP's acceptance is a factor 100 higher than 11 GeV/c LASS exp Hep-ex/0412031(2004) for this channel
- Missing Mass with 2% signal/backgd and .5% in MIPP for 3 and 5 GeV/c K+ beam momenta. In 12 days of running we can obtain sensitivity 2 orders of magnitude higher than LASS expt.



Timeline

- Run Till next shutdown in currrent mode
- Acquire Altro/PASA chips
- Design New TPC Sticks
- Get approval for proposal. We have appealed the PAC decision
- Get new collaborators
- Run in 2006 (end of 2006) in upgraded mode with current beam.
- Design lower momentum beam. Beam Cerenkovs may need redesign (too much multiple scattering)
- Lots of graduate student theses
- Possible to affect shower simulators on 2007 time frame.